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Transfer of Training and Retroaction

A Comparative Study

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CONTENTS

TRANSFER OF TRAINING AND RETROACTION

I. INTRODUCTION

This study deals with the problems of transfer of training, retroactive inhibition, and their possible interrelations. The maze activities were utilized as the material of study, and both human and animal subjects were employed in the experimentation.

The term 'transfer of training' has long been in use in educational literature. The question usually considered in reference to this idea is, whether or not the learning of one problem aids, hinders, or has no effect upon the acquisition of a second problem. We shall employ additional terms to designate the three possible effects above mentioned. The term 'positive transfer' will be used to denote the results obtained when the learning in the first situation aids the learning in the second situation. 'Negative transfer' will be the term used to denote the results obtained, when the learning in the first situation hinders the mastery of the second problem. There is also the possibility that the first learned material will have no effect upon the acquisition of the new material. In this case transfer of training will not be present. Results obtained in this last named instance will be referred to under the designation 'absence of transfer.'

The term 'retroactive inhibition' has been definitely recognized since the experiments of Müller and Pilzecker,[1] and this term refers to the disturbing effect that the learning of a second problem has upon the retention of material previously acquired. As with transfer, there are three possible retroactive effects. The second acquired material may aid, hinder, or have no effect upon the retention of the first learned problem. We shall use the term 'retroaction' to refer to any possible effect that a second activity may have upon the retention of a first problem. The term 'posi-

[1] Müller and Pilzecker. Experimentelle beiträge zur Lehre vom Gedächtniss. Ztsch. f. Psychol., 1900, Ergzbsbd. I.

tive retroaction' will be used to refer to the results when the second learned problem aids in the retention of the first problem. When the second problem interferes with the retention of the problem previously acquired, this result will be termed 'negative retroaction'; this last described condition is what Müller and Pilzecker termed retroactive inhibition. There is the further possibility, as was found by DeCamp,[2] that the second learned problem may have no effect upon the retention of the first problem. Such a case will be referred to by the term 'absence of retroaction.'

We believe that all three results have been obtained in the experiments on transfer. A positive or beneficial effect has been the usual result, and practically all the writers agree on the term positive transfer to denote this result. The term negative transfer seems to be employed to refer sometimes to the absence of any effect and sometimes to an inhibitive or detrimental effect. Terms are needed to discriminate between these two cases. Experiments on retroaction report but two types of results, either an interference or a lack of any effect. However, the possibility of all three effects must be recognized, and distinct terms are needed. Those suggested by this paper serve this need, and give the added advantage of a uniform terminology in comparing our two problems.

The maze was chosen as the basis of these experiments for three general reasons. (1) To study the phenomena of transfer and retroaction in a type of human activity somewhat different from those previously used, viz., an activity of a sensori-motor and adaptive character. (2) To investigate these phenomena in the animal as well as in the human realm. (3) To determine the essential similarity or difference between human and animal organization for these aspects of the learning process. The value of the maze problem for these purposes is obvious.

1. The experiments with human subjects on the problem of transfer have been rather adequately reviewed by Thorndike,[3]

[2] DeCamp: A Study of Retroactive Inhibition. Psych. Rev. Mon. Sup. vol. 19.

[3] Thorndike: Educational Psychology, Vol. 2.

and Coover.[4] There is no intention here of repeating this type of work. The object we have in view is simply to present a sufficient review of the literature to contrast the materials and methods previously used with those employed in this experiment. Our purpose is well served by following Coover's analysis. He classifies the experiments on transfer under the following topics. (1) Habituation to distraction. Vogt's work on testing the effect of reacting to a metronome, and reciting series of letters, upon the simultaneous activity of adding a column of figures serves as an example of this type of experiment. (2) Sensitivity. An illustration of this class is afforded by the work of Epstein, who sought to determine the influence of sound stimulations upon the acuity of simultaneous visual processes. (3) Discrimination. Bennett tested the effect of training in discrimination of shades of blue upon the dscrimination of shades formed by a mixture of two colors, and upon discrimination of pitch differences. (4) Association. Thorndike and Woodworth tested the effect of training in estimating areas, weights and lengths upon estimations of various other areas, lengths and weights, of a different character. (5) Reaction. Thorndike investigated the effect of training in marking out words containing both the letters *e* and *s* upon the ability to mark out words with different pairs of letters, such as e-g, i-t, s-p, e-r; the length of the lines, size of type, and style of reading matter varied in the test series from that which was employed for the same items in the training series. The effect of the above mentioned training was also tested upon marking out misspelled words and words containing the capital letter A. Bergström reports some experiments on discriminative reactions, which showed interference. He tested the effects of training in the sorting of cards by one method upon the ability to assort cards by a different method. (6) Memory. The work of James in memorizing poetry, Ebbinghaus' work on memorizing nonsense syllables, the experiments of Ebert and Meumann with nonsense and other material, serve as illustrations of the work done in this field. (7) Voluntary control.

[4] Coover: Formal Discipline from the Standpoint of Experimental Psychology. Psych. Rev. Mon. Sup. Vol. 20.

Judd and Cowling tested the effects of drawing an imaged form with the eyes open upon the ability to draw the image with the eyes closed.

We wish to offer here criticism of one aspect of Coover's analysis. We are inclined to believe that his classification is too broad. We doubt the advisability of including under the term transfer of training his first and second headings. These have to do with the effect that one activity has upon a simultaneous activity. Undoubtedly some sort of interaction does obtain between two such activities. Transfer of *training,* however, implies the utilization of the effects of training or a learning process upon some subsequent activity. Coover's two classes deviate from this definition in two respects. The first activity hardly involves anything that may legitimately be termed training or learning, and the effect is upon a simultaneous and not upon a subsequent process. Coover, however, discusses these experiments under the topic of 'Formal Discipline,' but to our mind, the two terms formal discipline and transfer of training, have been used as synonyms in the literature.

In further considering this classification, it appears to us that three divisions, which Coover does not mention, may be added. (8) Attention and Reproduction. Coover used in his experiments some of the methods and materials mentioned under the above headings, such as marking out words, estimating weights, and discrimination problems. He also performed experiments with other materials that we would classify under another heading. In the experiments on attention Coover tested the effects of training in activities which involve a large amount of attention such as, tachistoscopic work, learning 12-letter-rectangles, reactions to sounds, and memory training, upon such activities as reactions to sounds, marking out a's and o's, card sorting, memory of visual signs, trains of ideas, tapping, and many other activities. The difference in attention was noted between the training work and the testing series. In the reproduction experiments the effect of training in sound discrimination was tested upon such activities as recognition of one or two letters, reproduction of letters, sound discrimination, and memory for visual

symbols. (9) Cross education. The experiments on cross education note the transfer to one hand or foot from a training of the other hand or foot. The experiments of Davis,[5] and Johnson[6] with tapping; those of Woodworth[7] on hitting a dot with a pencil; the ones of Swift on tossing balls; and those of Starch on tracing an outline seen only in a mirror are cited as illustrations of work in cross education. (10) Sensori-motor learning of an adaptive character. At the meeting of the American Psychological Association, 1915, Dr. Frank N. Freeman reported some tests made by him on transfer in sensori-motor learning. This is a study of mirror drawing. The apparatus was so constructed that it was modifiable in such a way as to vary the conditions indefinitely. The problem in these experiments was to test the effect of learning to connect six dots with a pen, with the mirror in one position, upon learning to connect the six dots with the mirror in another position.

There are marked variations in the results from the various experiments on transfer of training. In summarizing the experiments, following his review, Coover interprets the results in most instances as evidence of positive transfer; he recognizes, however, several instances of negative transfer. Thorndike, in his review of the literature, gives the reader a strong impression that the evidence for positive transfer is rather weak. This is indicated by the following quotation. "These experimental facts as a whole, like those concerning memory, leave a rather confused impression on one's mind, and resist organization into any simple statement of how far the improvement wrought by special practice spreads beyond the function primarily exercised."[8] We are of the opinion that some of the experiments demonstrate the existence of a decided positive transfer. Bennett showed that training in memorizing poetry improved memory for digits and names of places; Ebert and Meumann proved that training for nonsense syllables improved the memory for letters, numbers, words, poetry, prose and optical symbols. Some of the results

[5] Davis: Researches in Cross-Education. Yale Studies, Vol. 4.
[6] Johnson: Researches in Practice and Habit. Yale Studies, Vol. 4.
[7] Cited by Thorndike. Op. Cit. p. 366.
[8] Op. Cit. p. 416.

also demonstrate the existence of negative transfer. A splendid illustration of this is found in the work of Bergström, wherein he showed that the training in the sorting of cards by one method interfered with the sorting of cards by a new method, and that in learning series of nonsense syllables successively, the time becomes progressively longer if the series possess recurring elements. Further, we believe that some of the results indicate an absence of transfer. An illustration of this is taken from the work of Sleight as reviewed by Thorndike[9]: Sleight's results show that training in memorizing poetry has very little, if any, effect upon the memorizing of tables of figures or prose. James interpreted his own experiments on memory as evidence of an absence of transfer. Some of Thorndike and Woodworth's experiments give evidence of little or no transfer.

We have seen that the materials employed in the experiments on transfer vary from those of a purely ideational character, such as memorizing poetry or nonsense syllables, to those having less and less of an ideational character; in some of the experiments, such as those dealing with visual and auditory discriminations, the sensory elements predominate; there are also experiments dealing mainly with material of a sensori-motor character such as those of Freeman referred to above. The material used in our experiment is more nearly like that employed by Freeman. The maze activities are essentially sensorimotor in character. The sensori-motor element predominates in mastering a maze situation. This is the universal conclusion of all experimenters with such animals as the white rat. The rational element is present with human subjects, but it is recognized that these ideational activities function with little effectiveness in the mastery of the problem. The sensory elements employed are what James calls resident sensations. Under the conditions of our experiment the effective sensory factors are tactual and kinaesthetic in character.

There have been no published experiments dealing specifically with transfer in the animal field; neither has the maze activity been utilized in the study of this phenomenon with human sub-

[9] Op. cit., p. 379.

jects. Perrin[10] used the same subjects in the learning of the several mazes in his experiments, but he made no definite report of the transfer effect.

There have been no experiments on retroaction which employed sensori-motor activities. Only three important studies with human subjects have been reported. Müller and Pilzecker[11] investigated the retroactive effect of memorizing nonsense syllables and observation of pictures upon the retention of previously learned material. They reported that such subsequent activity exerted a negative or inhibitive effect upon the retention of the first learned series. DeCamp[12] investigated the retroactive effect of such activities as memorizing nonsense material, multiplying a series of numbers, the solution of various problems, and playing chess, upon the retention of previously mastered material, and he decided that no retroactive effect was present in his experiments. Heine[13] repeated Müller and Pilzecker's experiments and verified the former results; she also discovered negative retroaction between the letters of the syllables; she made further tests for retroaction employing recognition instead of learning, and here she failed to secure evidence to prove the presence of a retroactive effect.

It will be noted that Müller and Pilzecker investigated the retroactive effect of two similar activities of an ideational character. DeCamp also used activities of an ideational character, and employed dissimilar as well as similar activities. We shall also use two similar activities in our experiments—the effect of one maze activity upon another—but shall employ sensori-motor activities rather than those of an ideational character. This difference of material is significant because of a possible difference in the stability of the two types of activity. Results obtained from stable material may thus indicate that the existence or degree of negative retroaction may depend in part upon the

[10] Perrin: An Experimental and Introspective Study of the Human Learning Process in the Maze. Psych. Rev. Mon. Sup. Vol. 16.

[11] Op. cit.

[12] Op. cit.

[13] Heine: Über Wiedererkennen und rückwirkende Hemmung. Ztsch. f. Psychol., 1914, Band 68.

stable character of the activities employed in the experimentation.

The results of DeCamp suggest the further possibility that retroaction may be in part dependent upon the similarity of the two activities employed. For this reason we decided that it would be better to utilize two highly similar processes. Our method deviates from that of DeCamp, and Müller and Pilzecker in two other important respects: (1) The temporal relation of the two activities. Their first activity is learned with continuous trials in a single sitting, while the second work is performed within five to fifteen minutes subsequently. Rats of necessity master the two mazes with a distribution of trials extending over several weeks, with at least a day's interval between the completion of the first maze and their introduction to the second. The same distribution of effort was maintained for the human subjects in order to secure comparable results in the two cases. (2) The method of measuring retention. The previous experiments measured the amount retained after the interpolation of the second activity by the usual method of verbal reproduction. Such a method is impossible with the maze problem. In our experiment retention was necessarily measured by the relearning method.

2. Our second purpose is justified by the fact that there has been little or no systematic work done on either problem in the animal field.

Many of the early workers in the animal field incidentally noted and commented upon the presence of transfer when animals used on one problem were employed on some other task.[14] There are but three systematic works on this subject with which the author is acquainted. One was reported by Mr. H. H. Wylie at the meeting of the American Psychological Association, 1915. He trained white rats to respond to a certain stimulus, e. g. light or pain, in a given situation. After this habit was well established, the animals were taught to respond to a different stimulus in the same situation, and the degree of transfer between these

[14] Watson has given an excellent review of the literature in this field in his text, "Behavior, An Introduction to Comparative Psychology." Chapter VI.

two highly similar situations was measured. Hunter[15] demonstrated with white rats that the acquisition of an auditory-motor habit interfered in the formation of a new habit of opposite character. Pearce[16] has demonstrated the same result, duplicating the conditions of Hunter, but employing visual-motor habits.

Within the knowledge of the author of this paper, no experiments on retroaction in the animal field have been reported.

3. We also wished to determine whether the laws and conditions of transfer and retroaction are the same for both humans and animals; whether human and animal organizations are essentially identical in kind.

Thorndike,[17] in elaborating the laws of learning, maintains the validity of the above proposition. Most Comparative Psychologists would subscribe to this belief, but it is a belief or generalization which represents to a large degree a working hypothesis, the testing of which Comparative Psychology recognizes as one of its main tasks. Thus far Comparative Psychology has demonstrated the hypothesis in many respects, e. g. both humans and animals can learn, and both can learn by the same method. However, the proposition is not completely demonstrated in every respect, and we wish in these experiments to test the hypothesis in two additional phases, transfer of training and retroaction.

To test the proposition that the laws of learning are the same for humans and animals, it is advisable to secure comparisons where the problems and conditions are as similar as possible. Many more comparative statements and generalizations could be made from the work already done, if similar situations had been used. So far as the author is aware, there have been only three experiments reported, wherein the identity of the problems and situations was maintained to an important degree. Hicks and Carr[18] compared the ability of white rats and humans in

[15] Hunter: The Interference of Auditory Habits in the White Rat. Jour. Animal Behav., Vol. 7, No. 1.

[16] Pearce: A Note on the Interference of Visual Habits in the White Rat. Jour. Animal Behav., Vol. 7, No. 3.

[17] Op. Cit., p. 12f.

[18] Hicks and Carr: Human Reactions in a Maze. J. Animal Behav., Vol. 2.

learning the maze problem. The two problems were similar in kind, but the mazes were not identical in pattern, and some other conditions differed so that their situations were not as similar as they might have been. Hunter[19] was the first one to study humans and animals with conditions and problems identical. He tested animals and children on the problem of delayed reaction. The identity of the two situations was maintained as far as possible, and he found that the period of delay in the reaction could be lengthened as he ascended the animal scale from rodents, dogs, primates, and children. Pechstein[20] has studied various methods of motor learning, using animals and humans in learning the maze. His maze patterns, his technique and method of procedure were similar to a marked degree. Our experiment is only one more step of the many that are needed in the comparative field to test the above hypothesis. The effort was made to have the situations as comparable as possible, and it is believed that another bit of evidence is added by this study towards the solution of this important problem.

In the experiments with the rats two adjustable mazes were used. They were the same in size, 4′ x 3′8″ x 6″. These mazes were made of ½″ stuff and were covered with glass. Each maze was placed upon a frame about eighteen inches high. The runways and the cul de sacs were four inches in width. The partitions within the mazes were made of galvanized sheet iron, and were set in brass supports, so that they were easily moved back and forth. This construction gives large possibilities of altering the location of the cul de sacs in relation to the true path. Six different maze patterns were thus constructed and utilized in the experiments with rats. These patterns will be hereafter designated as Mazes A, B, C, D, E, F. They are represented in Figures 1 to 6.

The mazes used for the human experiments are known as 'pencil mazes.' Two of these were made from solid aluminum

[19] Hunter: The Delayed Reaction in Animals and Children. Behav. Mon. Vol. 2.

[20] Pechstein: Whole vs. Part Methods in Motor Learning. Psych. Rev. Mon. Sup. No. 99, Vol. 23.

castings and two from solid brass castings. The cul de sacs and the true runways were milled out of the castings, and were ¼" wide by ¼" deep. The partitions were ¼" wide, and the outside dimensions were 5¾" x 5¼". But four patterns were employed with human subjects, and these are designated as pencil mazes A, B, C, D. These four duplicate exactly, except on a reduced scale, the patterns of mazes A, B, C, and D respectively used with the rats. They were identical as to the location of runways and the cul de sacs. Each section of the true path, each turn in the true path, and each cul de sac had the same relative position in each type of maze. Not only did we have identity of maze patterns, but we endeavored to have the technique and method of experimentation, which will be described later, as similar as possible. The exact duplications of maze patterns and the identity of method of procedure for rat and human subjects were adopted in order to achieve our third object mentioned above, the comparison of human and animal results upon identical problems.

The rats used in this experiment were thoroughly tame, having been fed for a week in the maze before the experimentation began. The animals were kept in the same room where the experiment was performed, and the location and conditions of their living cage were not changed during the experimentation. When the cages were cleaned, this work was always done after the experiment of the day was finished, thus giving the rats twenty-four hours to become adjusted to the disturbance. The work of each day was done in the late afternoon. Before the experimentation began the window shades were lowered and the electric lights were switched on, thus giving uniform lighting conditions throughout the experiment. The animals were run under a stimulus of normal hunger. Each animal was given one trial per day for the first four days and two trials per day thereafter until the maze was mastered. At the end of the first trial the animal was allowed a bite or two or food, and then immediately was given his second trial. When the group had finished the day's work, they were allowed to eat for seven minutes of a diet of bread and milk; at intervals sunflower seed was added to the

diet. In the experiment on transfer, after each subject had mastered the first maze, he was transferred to the second maze on the following day. The same method of procedure obtaining in the learning of the first maze was continued during the mastery of the second maze. During the period in which the rats were not running the maze, they were each day taken from the cage and allowed to run on the top of a table for exercise. They were fed as during the experiment outside of the cage. This was done in order to maintain the normal conditions of the experiment and to obviate any disturbance until after the tests for retention were given. The results presented in this paper were obtained from one hundred and thirty-six white rats. The animals were from seven to twelve weeks old at the beginning of the experiment; they were in good condition and remained so throughout the tests. Males and females were in each of the groups in the separate parts of the experiment.

The human subjects upon entering the room in which the experiment was conducted, were seated at one side of a table. On this table the pencil maze was placed. Light strips of wood were nailed to the table at each side of the maze to prevent any movement when a subject was working on it. On the table, and covering the maze, was a frame one foot high on one side and one and one half feet high on the other side. The frame was eighteen inches wide and sixteen inches deep, and was covered with a heavy black cloth which hung loosely on the side towards the subject, and adequately hid the maze from his sight. The higher end of the frame opposite the subject was uncovered. This arrangement left the maze in full view of the experimenter, so that all errors were easily noted. This method was adopted in order to eliminate the disconcerting effect of a blind-fold, and to secure a comparable situation as to vision for humans and animals. The human subjects traced the maze with a stylus made of hard rubber. A shoulder about one inch from the lower end prevented the hand from slipping and coming in contact with the maze. The lower end of the stylus was 3/16″ in diameter and the pathway, being ¼″ wide, permitted easy contact with both sides. Each subject was given the following instruc-

tions: "Please put your hand under the cover; grasp the stylus and hold it as erect as possible with comfort; keep the stylus in the groove, and explore the area assigned until you are told to stop. Use any method you desire and think as much about the problem as you wish during the experiment, but do not try to draw the area and try not to think about the problem during the interval between successive trials." At the end of the run there was an opening in the pencil mazes, corresponding to the food box in the other mazes. This enabled the subjects to know when the end was reached, and thus they had to be told when to stop working for only one or two trials. One trial per day was given to each subject for the first four days and two trials per day thereafter until the problem was mastered. Sunday necessarily had to be omitted with the human subjects. When each subject had mastered their first maze, the following day he was transferred to the second maze. None of the subjects knew that the experiment was dealing with the problem of transfer and retroaction, and in no instance was a subject told that the maze had been changed; he discovered the new situation by going through it and noting the disturbance. A large part of the subjects were naïve, and knew nothing of the maze problem. Here again we notice the similarity of the procedure for humans and animals; each had to discover the new problem empirically. When a human subject finished the first part of the experiment, he was asked to come back at some later specified time for another part of the experiment. Each subject was requested not to think about the problem any more than possible, nor to try to draw the maze pattern during the interval. In the test for retention, the same instructions were given, and the same conditions were maintained as were used in the first part of the experiment. At no time was a subject told that this other part of the experiment was to be a test for retention. The subjects, fifty-two in number, were graduate and undergraduate students, all of whom were studying psychology in the University of Chicago. There were both men and women in each of the groups that were used in the various parts of the experiment.

Individual time and error data for each trial were recorded.

The time in seconds was measured with a stop watch. The time for each trial was counted from the moment the subject entered the maze until he reached the entrance to the food box. No record of the distance traversed was kept, as this was practically impossible under the conditions here maintained. We agree with Mrs. Hicks[21] in her emphasis upon the distance traversed, as a criterion for measuring the learning process in a maze situation. However, our method of counting errors overcomes, to a large extent, this deficiency; each section of the true path, no matter how short, was counted an error in retracing. The unit of error was one section of the pathway. Each entrance into a cul de sac, whether for all or part of its length, each retrace over the whole or a part of a section of the true pathway, was counted an error. The errors due to entering a cul de sac while going forward, the errors due to entering a cul de sac while returning home, and the errors due to retracing the true pathway, were kept separately. The criterion of mastery was four perfect trials out of five, and in these five trials not more than two errors were allowed.

The comparableness of the technique and methods of procedure for both types of subjects is obvious. The maze patterns are identical, the mazes for the humans being duplicates of those used with the rats, with the exception of a difference in size. The methods of recording the data were the same; the distribution of effort is practically the same. Watson[22] has shown that rats make very little use of vision in mastering the maze problem; the rats have eyes, but do not use them in this situation. With the technique here maintained, it can be said that the humans have eyes but do not use them in this situation, and further the disconcerting effect of a blind-fold is absent. Both humans and animals come to the problem naïvely. The humans were not informed as to the situation; they had to discover their problem as did the rats. This last condition was more fully maintained

[21] Hicks: The Relative Value of the Different Curves of Learning. Jour. Animal Behav., Vol. I.

[22] Watson: Kinaesthetic and Organic Sensations. Psych. Rev. Mon. Sup. Vol. 8.

with the human subjects who learned pencil mazes C and D. These subjects knew nothing of the problem until after they worked on it. The groups that learned pencil mazes A and B, involving transfer, were graduate students in Psychology and were well enough acquainted with the experiments being carried on in the laboratory, to know that this experiment was dealing with the maze problem. The results of the naïve and sophisticated groups were compared, and only minor differences, such as can be accounted for in terms of chance differences, were noticeable. However, all of the human subjects came to the transfer and the tests for retention naïvely, as did the rats, as nothing was said to any of the subjects to indicate the changes. During the interval that the rats were not running the maze, the conditions of exercise and feeding were not changed, so normal conditions obtained when they returned to the maze for testing retention. The human subjects went about their normal activity, and were asked not to think about the problem, nor to try to draw the area during the interval. Thus it is observed to what extent we endeavored to keep the conditions similar for the two types of subjects. By these means our third purpose mentioned above is well served, and our conclusions in comparing the transfer and the retroactive effects on humans and rats are rendered more valid.

II. TRANSFER OF TRAINING

A. Dependence of Transfer upon the Character of the Second Problem.

The object of the first experiment is to determine to what extent the nature and degree of transfer is a function of the second problem.

In educational literature there has been much discussion relative to the question of the general spread of training. The classical argument has been that the study of Latin or Greek improves the intelligence of the student in such a manner that said learner will be able to acquire more easily any other subject he thereafter studies. This statement seems to imply that the existence of any transfer effect in subsequent situations depends wholly upon the character of the previous training. The other side of the question must also be recognized, viz. that the functional efficacy of classical training may depend in large part upon the nature of one's subsequent mental activity—that it may have more effect in the life activities of a lawyer than of an electrical engineer. Our first experiment was designed to solve this latter question, not that we experimented with the Classics and other strictly intellectual subjects, but rather that we were concerned with the solution of the problem in the realm of motor learning.

In terms of mazes the problem is readily illustrated. Several groups of subjects first learn a common maze A, and each group subsequently learns a different maze. One group is thus transferred from Maze A to Maze B, another from A to C, one from A to D, another from A to E, and one from A to F. If the nature and degree of the transfer is wholly a function of the first maze, fairly uniform results should be secured for all groups. The group differences should be only such as can be attributed to chance or group factors. Marked variations in the results would indicate, on the other hand, that the nature and degree of transfer is in part a function of the nature of the second maze.

In our experiment six groups of subjects first learned Maze A. These groups comprised a total of 54 rats and 21 humans. A group of nine rats and a group of five humans were then transferred to Maze B; a group of eleven rats and a group of six humans subsequently learned Maze C; a group of six rats and one of five humans were transferred to Maze D; a group of eight rats then mastered Maze E, and a group of nine rats subsequently learned Maze F.

The transfer effect is measured by the difference between 'original learning' and 'transferred learning.' By original learning we mean the acquisition of a maze by a group of subjects without previous maze experience. By transferred learning we refer to the mastery of a maze by a group with a previous maze experience. Thus control groups were necessary for Mazes B, C, D, E, F, in order to secure data on the original learning. These control groups consisted of 20 rats and 10 humans for Maze B, 11 rats and 10 humans for Maze C, and 13 rats and 11 humans for Maze D. No human subjects were employed on Mazes E and F, and the control groups for these mazes consisted of 16 and 15 rats respectively.

Table 1 presents the results in the absolute terms of averages for our first experiment. The transfer effect was measured separately in terms of trials, errors and time, thus giving us three criteria of measurement. The group averages, together with the average deviation, for the original and the transferred learning are given for each of the criteria. The letters in the table indicate the records for the several mazes; thus *B* indicates the record for the original learning of that maze, and A-*B* denotes the transferred learning of the same maze. The A in connection with the A-*B* means that Maze A constituted the previous maze experience of the group. The symbol Sav. refers to the average amount saved for each group and these figures thus measure the transfer effect for each group. Table 2 states the saving in relative or percentage terms. These percentages of transfer are secured by dividing the absolute amount saved for any maze by the figure measuring the original mastery of that maze. If 12 trials are saved in transferring to Maze B, while 15 trials were

Table 1. Comparative Records of Original and Transferred Learning.

Rats

	Trials	Errors	Time
B	56.2±14.7	224. ±71.8	2468.6±1614.3
A—*B*	12.9± 9.	31.8±20.3	400.5± 200.2
Sav.	43.3	192.2	2068.1
C	45.7±14.5	238.5±76.9	2939.4±2504.5
A—*C*	18.3±14.2	129.3±78.3	1902.2±1261.8
Sav.	27.4	109.2	1037.2
D	16.7± 8.1	153.6±51.	2777.3±1272.4
A—*D*	5.2± 4.4	31.2±20.6	487.1± 218.6
Sav.	11.5	122.4	2511.1
E	4.4± 2.5	19. ± 6.	213.5± 75.5
A—*E*	3.5± 1.5	8.6± 5.9	78.1± 53.6
Sav.	.9	10.4	135.4
F	27.9±10.1	128.5±39.2	1209.8± 447.7
A—*F*	10.3± 6.1	73.8±37.	490.7± 294.7
Sav.	17.6	54.7	719.1

Humans

	Trials	Errors	Time
B	33.6±14.3	285.2±205.4	1166. ±514.2
A—*B*	10.8± 5.9	32.4± 13.7	149.4± 54.7
Sav.	22.8	252.8	1016.6
C	38. ± 9.8	133.7± 43.8	736.4±124.2
A—*C*	30.5±13.	106.8± 44.5	521.5±168.1
Sav.	7.5	26.9	214.9
D	11.6± 6.9	203. ±176.	773.5±498.
A—*D*	5.6± 3.3	11. ± 10.	87.2± 64.6
Sav.	6.	192.	686.3

expended in its original mastery, it is evident that the effects of the transfer represent a saving of 80%. The symbols of this table have the same meaning as in Table 1.

Upon the basis of the data presented in these tables, we are able to make the following conclusions, which will be illustrated and discussed.

1. The nature of the transfer is positive for all five pairs of mazes for both humans and animals, and by all three criteria of measurement. In no instance is there any evidence of negative transfer.

The data of Tables 1 and 2 substantiate this conclusion. An

TABLE 2. AVERAGE PERCENTAGE OF SAVING IN TRANSFER.

	Trials	Errors	Time
RATS			
A—*B*	77.08	85.81	83.77
A—*D*	69.02	79.71	90.42
A—*E*	19.91	54.63	63.40
A—*F*	63.01	42.78	59.44
A—*C*	57.85	46.10	34.94
HUMANS			
A—*D*	51.98	94.58	88.73
A—*B*	67.86	88.64	67.18
A—*C*	19.74	20.20	29.18

examination of Table 1 shows that the averages of the original mastery for all three of the criteria are larger than for those of the transferred learning in every one of the twenty-four possible cases of comparison. It is observed in Table 2 that in every instance of measurement, in the five cases with the ~~human~~ rat subjects and the three cases with the human ~~rat~~ subjects, a considerable percent of saving is shown to exist. It will be observed that the lowest percentage of transfer measured by trials is a fraction over 19%, by errors the lowest percentage is 20%, and by time the lowest record is 29%. From the lowest records, the percentage saved runs up as high as 77% for trials, 94.5% for errors and 90% for time.

These differences between the records for the original and the transferred learning may be due to three possible causes—chance, group differences, or the previous maze experience of the transferred group. We have evidence along two lines to prove that chance is not playing a very important role. It will be noted in Table 1 that the average deviations are rather wide, due perhaps to the small number in the groups. This fact throws some doubt on the validity of these differences. To test this we figured the Probable Difference for each of the twenty-four instances of comparison, and in every case, with but one exception, the actual difference was found to exceed the probable difference. There is the further important fact of the consistency with which the differences occur. In the eight cases of comparison of the original and transferred learning, the records for the transferred learning are uniformly the lower; this uniformity

in the records can also be observed for each of the criteria of measurement; and it obtains for the transfer stated in both relative and absolute terms. Considering the above facts, we believe that chance differences can not be regarded as the primary causal factor in the results here obtained. Further, the possibility of group differences functioning sufficiently to produce the above results is obviated by our method of selecting the groups. The rats were bought in lots of fifty to one hundred; these were mixed and the groups were selected by chance, care only being taken that both male and female subjects were in each group. Thus the possibility of having a selected group of either a good or a bad strain, a highly intelligent group, or a group of low intelligence, is eliminated. The human subjects were secured from the large number of students studying psychology in the University of Chicago, and the grouping of these was a matter of chance with the exception that both men and women were put in each group. Again, the probabilities favor our not having groups of good or bad strain, or groups of high or low intelligence. Mathematically, the chances favor the validity of the differences; the uniformity of lower records for the transferred learning enhances this probability manyfold; further, the factor of group differences was overcome by our method of securing the various groups. To our mind, the results of this experiment prove beyond doubt the existence of a positive transfer.

The positive character of the transfer is significant in view of the fact that an effort was made to so arrange the relations between some of the maze patterns as to secure a negative effect. Mazes A and B were constructed on a highly similar design with the expectation of securing a positive effect, and we were not disappointed in the results. Compare Figures 1 and 2. In designing the other four maze patterns, we aimed to secure negative results and in every case we failed to realize our purpose. The principles governing the designing of these patterns may be briefly mentioned. Maze C was so arranged that in transferring to it from A, the general direction of travel would reverse the older habits of the subjects. This fact is evident from a comparison of the patterns represented in Figures 1 and 3. Maze D

presents such an arrangement of cul de sacs, that the older habits acquired in Maze A would tend to produce many cul de sac entrances. Compare Figures 1 and 4. Simplicity, or ease of mastery governed the construction of Maze E, on the hypothesis that a transfer from a difficult to an easy maze might conduce to a high degree of confusion or disturbance. Maze F differed from A, both in conflicting arrangement of cul de sacs, and in a considerable shortening of the length of the true path. By a comparison of the patterns in Figures 1 and 6, it will be observed that in the transfer from A to F the subject must learn to omit the section numbered 6 to 10 which corresponds to a section of the true path in A. As we have stated, none of these arrangements operated to produce a negative transfer effect. However, we do not mean to assert that a negative effect between two mazes is impossible.

2. Transfer is a composite process consisting of both positive and negative elements. The acquisition of any maze may both hinder and aid in the mastery of a second maze, although the total effect is positive.

The proof of the above proposition is found in a comparison of the original and transferred learning of Maze F. In the preceding topic we noted the relation of section 6-10 in Maze F to the corresponding part of Maze A. These parts are so related that rats trained in A should possess some tendency to enter section 6-10 in the subsequent mastery of F, and naturally any undue tendency to enter these cul de sacs will be detrimental to its mastery. The hypothesis that the habits acquired in A did exert such a detrimental effect is proven by a comparison of the records of the test and control groups for this section. Rats previously mastering A—the test group—entered this section much more frequently and experienced a greater difficulty in eliminating the tendency than did the control group—animals without such training.

(1) The test group required a greater number of trials to eliminate this section. Our criterion of mastery was five successive runs without entrance. The average for the test group was 8.22, for the control group 6.15. Stating the values in rela-

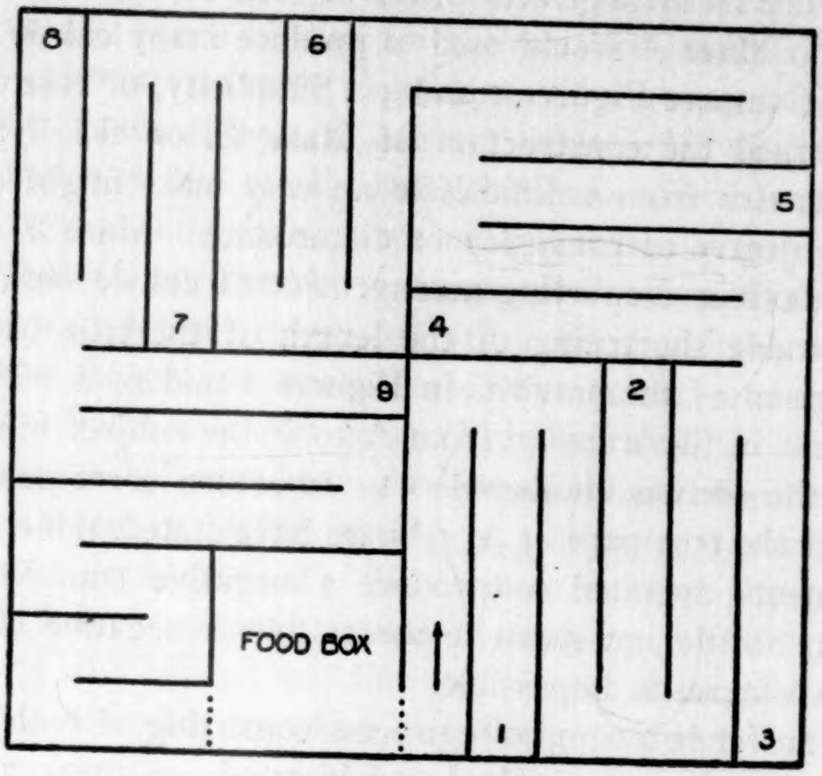

FIGURE 1: MAZE A.

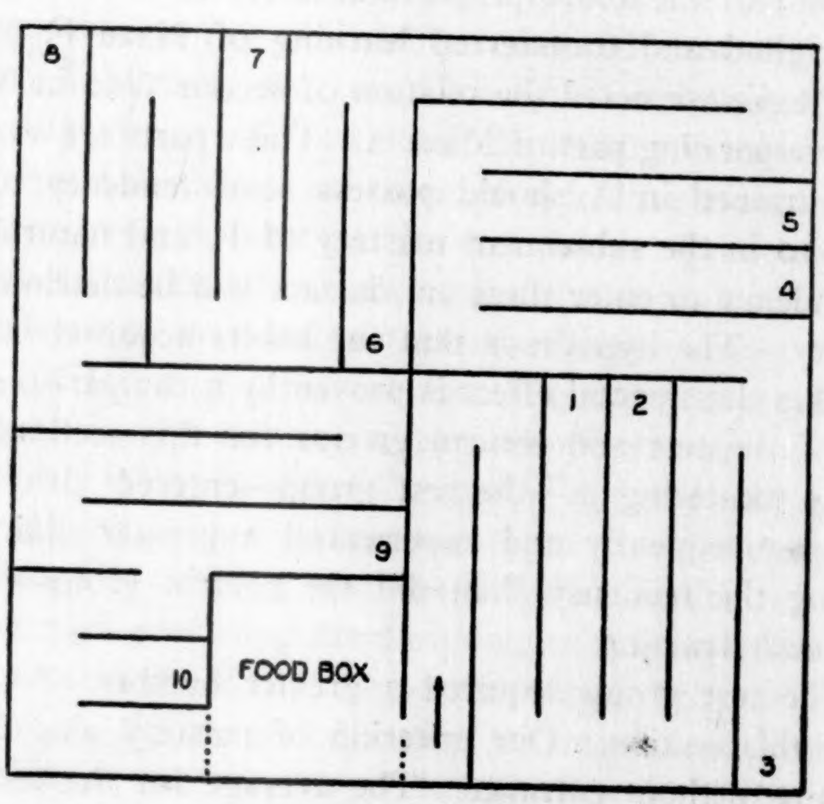

FIGURE 2: MAZE B.

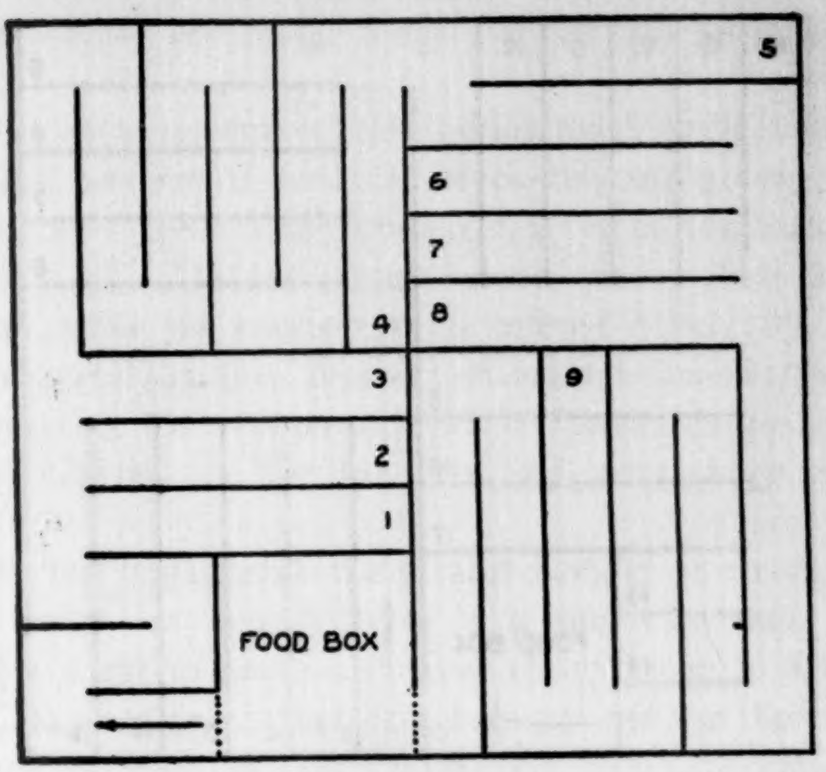

FIGURE 3: MAZE C.

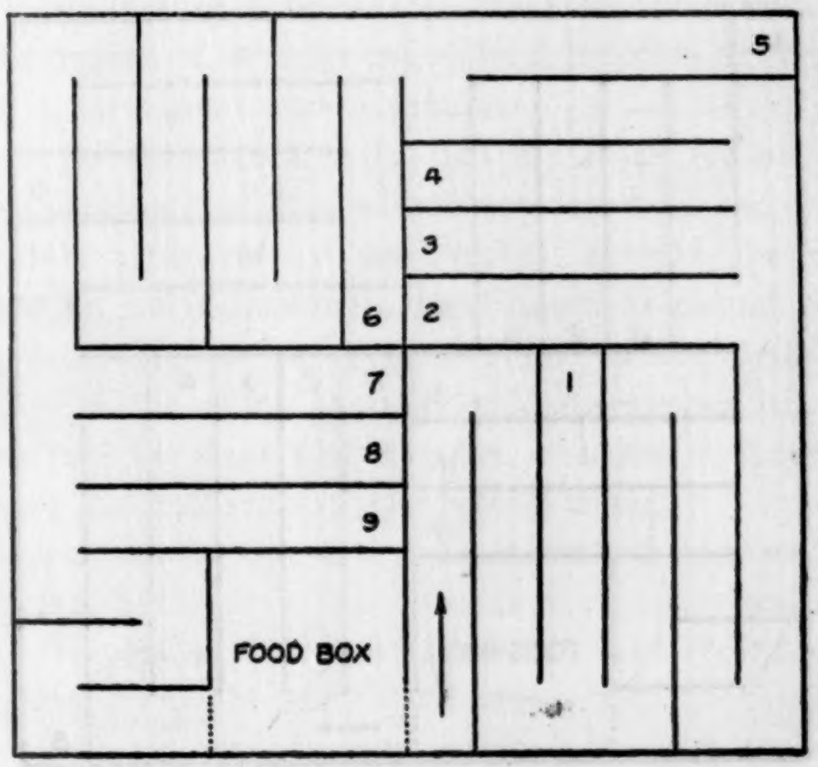

FIGURE 4: MAZE D.

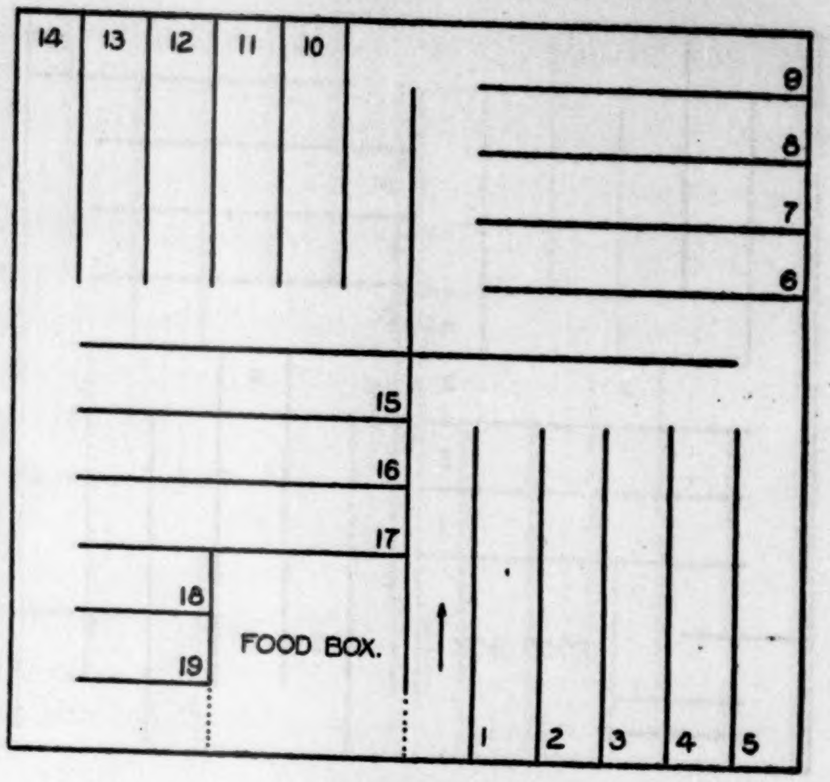

FIGURE 5: MAZE E.

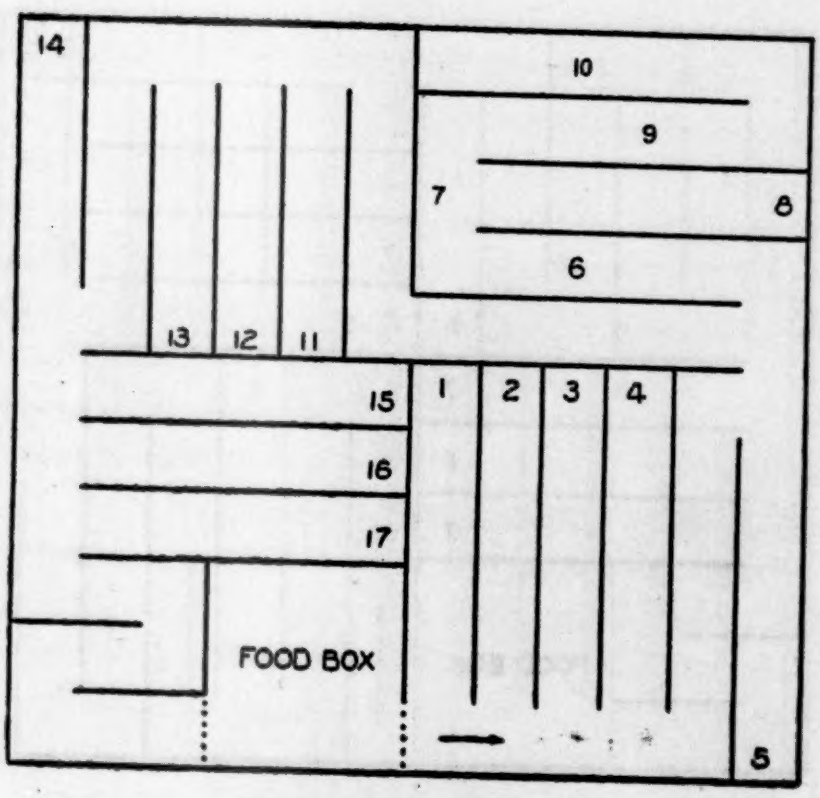

FIGURE 6: MAZE F.

tive terms, the test group required 79.5% of its total trials, while the corresponding percentage value for the control group was but 22%.

(2) The test group entered this section much more frequently. The average number of trials in which the test group entered this section was 5.88. The corresponding value for the control group was 5.15. The test group entered this section in 56% of its trials while the control group entered it but 18%. The animals frequently entered this section several times in the same trial; comparing the average number of entrances per rat, the values are 9.0 and 7.1 for the test and control groups respectively.

(3) The test group made the greater number of errors in this section. Since our unit of error is a single runway, it was possible for a rat to make a number of errors in a single entrance. The average number of errors per rat for the test and control groups were 30.4 and 24.0. Of the total number of errors made by the test group in mastering the maze 41.2% were due to this section. The corresponding value for the control group was 10.8%.

3. The third feature to be noticed from the above data is the fact that the degree of transfer is in part a function of the activities set up in the second maze situation.

Maze A is the constant activity, and the other five mazes are the varying processes of the second problem. If the transfer effect is mainly a function of the constant activity, the amount saved should be fairly uniform; the differences should be only such as can be accounted for by mere chance, or slight individual differences. On the other hand, a wide divergence of results will indicate that the degree of transfer is in part a function of differences in the character of the second maze.

Upon inspection of Table 1, it is found that the amount saved is not uniform, but rather that the range of the variations is quite wide. We discover wide variations in the average amount saved measured by trials, errors and time. The average saving for trials in the rat records vary from .9 to 43.3, and in the human records from 6 to 22.8. The averages for errors with

the rats vary from 10.4 to 192.2, and with the humans from 26.9 to 252.8. Similar results are observed in the time records; the rats vary from 135.4 to 2511.1, and the humans from 214.9 to 1016.6. Likewise, the results, stated in relative terms (see Table 2), indicate that the percentage of transfer varies with the change of the relation between the two activities.

Two possible explanations can be offered to account for these marked variations in the degree of transfer; either these are due to mere chance, or they are a function of the second activity.

The dependence of the degree of transfer upon the second maze activity is proven by the fact that the actual amount saved in each case is roughly proportionate to the original learning records of the five mazes. This fact is evident from an inspection of the data of Table 1. Considering the results for trials in the rat records, the largest saving (43.3 trials) was secured in the transfer from A to B, and B was the most difficult of the five mazes in terms of number of trials necessary to master. Likewise, the smallest amount saved (.9 trials) was secured in transferring to E, and this maze presented the least difficulty in original mastery. This relation between amount saved and the original learning records for any maze is also evident from Table 2, which states the actual amount saved for any maze in percentage terms in reference to the data for original learning. If the amount saved depended absolutely upon the difficulty of the second maze, these percentage data should be exactly the same for the five pairs of mazes. Provided there is only some degree of correlation between the two sets of data, uniformity of percentage data would not obtain, but the range of divergence for these relative data should be much less than that for the data of Table 1, giving the amount saved in absolute terms. Stating the transfer effect in relation to the corresponding learning data (Table 2), does decrease the range of divergence. For example, the saving for the rats varies between the extremes of .9 and 43.3 trials, and this divergence is decreased to 19.91 and 77.08 when estimated in relative terms; a better example is found by comparing the transfer to B with that to F. The absolute records represent a saving of 43.3 and 17.6 trials respectively, while the corresponding percentage records are 77.08 and 63.01.

The dependence of the amount saved upon the original learning records of the second maze, is also proven by the fact that a positive correlation obtains between the two sets of data. The discussion of this correlation phenomenon will be reserved for the succeeding topic.

4. A positive correlation exists between the degree of transfer and the difficulty of the second problem.

In the preceding topic, it was maintained that the variations in the amounts saved is in part a function of the second activity. In supporting this statement, we offered as evidence the fact that the differences in saving are correlated with the relative difficulty of the second problem. We have computed the correlation between the degree of transfer and the difficulty of the second maze, between the amount of effort saved due to transfer and the amount of effort expended in the original learning. The materials for this correlation are easily obtained from Table 1. The correlations were computed by the ranking method, and Table 3 presents the results for trials, errors, and time.

TABLE 3. CORRELATION BETWEEN DEGREE OF TRANSFER AND DIFFICULTY OF SECOND MAZE.

	Trials	Errors	Time
Rats	1.00	.70	.70
Humans	.50	1.00	1.00

A positive correlation obtains in the table by all three of the criteria and for both humans and animals. With the rats a perfect correlation exists for trials, and plus .70 for errors and time. In the human records we find a perfect correlation in the matter of errors and time, and a value of plus .50 by the criterion of trials.

In view of the fact that these values are based upon but five mazes for the animals, and upon three for the humans, one can not credit the validity of any single value, especially those as low as .50. The validity of the results must depend rather upon their *uniformity*. A positive correlation was obtained in every one of the six cases, and this fact enhances the probability of the validity of any single measurement manyfold. On the other hand, one must not be embued with scepticism because a

perfect correlation was not obtained in every case. Our conclusion merely states that the degree of transfer depends ***in part*** upon the difficulty of the second maze. Subsequent records will prove that the transfer effect is also a function of the first maze, and hence a perfect correlation with the data for either of the two mazes is not to be expected.

5. A positive correlation exists between the degree of transfer and the similarity of two maze patterns.

The main difficulty in a comparison of this kind concerns the measurement of the degree of similarity between any pair of mazes. One of the current theoretical explanations of the phenomenon of transfer is stated in terms of the partial identity of the neural elements existing between the two activities. Any measurement of such a relation between two activities is necessarily impossible.

In this experiment, we employed two methods of measuring the similarity of a pair of maze patterns. The first method used was that of 'order of merit' or 'relative position.' Nineteen individuals, who understood the maze problem, were asked to rank the five mazes in order as to their similarity to Maze A. They were asked to judge the similarity upon the basis of the two factors of the positional relation of the true pathway and the cul de sacs, and the direction of the course of travel. The results of these nineteen judgments were as follows: B was placed in first place 17 times and in second place twice; D was ranked second 17 times and first two times; C was given fifth rank by 14 and third rank by 5. The most difficult task concerned the ranking of E and F. The majority (11 out of 18), however, gave F the preference. From these judgments the mazes were ranked as follows: B-1, D-2, F-3, E-4, and C-5. The rankings as to the degree of transfer were determined from Table 1.

The results of the computations are given in Table 4. It will be noted that the correlation is positive by each of the criteria for both humans and rats. As regards trials there is the result of plus .30 for the rats and plus .50 for the humans. The record by errors gives a correlation of plus .70 for rats and 1.00 for

TABLE 4. CORRELATION BETWEEN AMOUNT SAVED IN TRANSFER AND SIMILARITY OF MAZES.

	Trials	Errors	Time
Similarity by Order of Merit.			
Rats	.30	.70	.60
Humans	.50	1.00	1.00
Similarity in Terms of Difficulty of Mastery.			
Rats	.70	.90	.30
Humans	.50	.50	1.00

humans; in the time records the rats have a correlation of .60 and the humans 1.00. Some of the values are high enough to indicate a valid correlation. Other values are so low that little importance can be attached to their significance when regarded singly. The validity of the results must depend primarily, not upon individual instances, but upon their uniformity. Some degree of positive correlation obtains for all six measurements, and this fact enhances their probable significance manyfold.

The second method measured the similarity of a pair of mazes in terms of their relative difficulty of mastery. If Maze A required forty trials for its mastery, while Mazes B and C were mastered in thirty and fifteen trials respectively, it is evident that A and B are more similar in respect to difficulty than are A and C. The five pairs of mazes can thus be ranked as to relative difficulty in terms of trials, errors, and time from the comparative data of Table 1.

These correlations are also given in Table 4, and a positive value again obtains for the six comparisons. The validity of these correlations again depends upon their uniformity.

We also compared the ranking as to similarity by the first method with the three sets of ranks obtained by the second method. The correlation value for trials was minus .30, while positive values of .50 and .60 were obtained for errors and time respectively. This indicates that any judgments as to the relative similarity of pairs of maze problems will anticipate more correctly their relative difficulty when measured by time and errors than by the factor of trials.

6. The transfer results are somewhat similar for the human and animal groups. Evidently the laws and conditions governing transfer are not radically different in the two organisms.

Transfer obtained for both human and animal subjects and its character was positive or beneficial in both cases. However, the rats evidenced more ability in utilizing a previous maze experience in a new situation, which is proven by the fact that the rats effected a larger saving in the transfer. The difference is quite pronounced and obtains for each of the three pairs of mazes when the results are stated in either absolute or relative terms. This is evident from an examination of the comparative data of Table 5. Rats and humans differ little, however, when the transfer is measured by the saving of errors, but the difference such as it is favors the human subjects. The humans effected the greater saving of errors for two of the three pairs of mazes for both the absolute and relative methods of stating the results. Thus, on the whole, the rats were able to profit more from their previous tuition in Maze A when the effect is measured in terms of trials or time. The rats expended the greater amount of trials and time to master A and made the greater saving of trials and time because of this previous training in A. The humans, on the other hand, required the greater number of errors to master A, and likewise profited the most from this tuition when its effects are measured in terms of errors. This fact will be observed by a comparison of the records for the original learning of Maze A as given in Table 5. This difference between humans and animals as to the amount saved due to their previous experience in A would seem to be a result of the character of that training. In other words, the amount of

TABLE 5. COMPARATIVE RESULTS OF HUMANS AND RATS

	Trials		Errors		Time	
	Rats	Humans	Rats	Humans	Rats	Humans
	Absolute Amounts Saved.					
A—*B*	43.3	22.8	192.2	252.8	2068.1	1016.6
A—*C*	27.4	7.5	109.2	26.9	1037.2	214.6
A—*D*	11.5	6.	122.4	192.	2511.1	686.3
	Percentage Amounts Saved.					
A—*B*	77.08	67.86	85.81	88.64	83.77	67.18
A—*C*	57.85	19.74	46.10	20.20	34.94	28.19
A—*D*	69.02	51.98	79.71	94.58	90.42	88.73
	Records for Original Learning of Maze A.					
	38.9	24.3	205.9	231.2	1782.4	970.8

transfer would seem to be in part a function of the character of the training secured in the previous maze, a proposition which will be further demonstrated by the succeeding experiment. While humans and animals manifest some difference as to the amount saved, yet they are similar in the following respects: that pair of mazes which induces the greatest amount of saving for rats has a like effect with humans; mazes which give the least effect with humans produce similar results with the rats. This formulation is true for the transfer stated in either absolute or relative terms; the truth of the proposition may be determined by computing the correlation between the amounts saved for the two classes of subjects. These correlation values were determined separately for trials, errors, and time when stated in both absolute and relative terms. The rankings were secured from Tables 1 and 2 and the results are to be found in Table 6.

TABLE 6. CORRELATION OF TRANSFER BETWEEN HUMANS AND ANIMALS.

	Trials	Errors	Time
Absolute	1.00	1.00	.50
Relative	1.00	.50	1.00

It is observed from the above table that there is a perfect correlation for trials in both absolute and relative terms; for errors we have a perfect correlation in absolute terms and plus .50 in relative terms; for time the results are 1.00 in relative terms and plus .50 in absolute terms. Thus we observe that in six cases of comparison there are four perfect correlations, and two of only fifty. However, we again put forth the statement that we must not judge by a single case, but by all the cases. So the consistency of the positive results strengthens the probability of a high correlation between human and animal learning as regards the phenomenon of transfer.

These facts prove not only that transfer obtains for both the human and animal realms, but that human and animal organization is highly similar so far as the laws and conditions of transfer are concerned. It further indicates that the processes involved are highly similar, and that no factors, such as rational activities peculiar to the human subjects, are functioning in this process of transfer.

7. A positive correlation exists between any two of the three criteria of measurement.

The efficiency of the criteria used in measuring any part of the learning process, is a question of great importance. In measuring the transfer effect in this study we have employed three criteria, trials, errors, and time. The interdependent relation existing between any two of these criteria can best be determined by correlation. The correlation values were computed from the records of the individuals in each of the transferred groups. The ranking method was used, and the results are given in Table 7.

TABLE 7. CORRELATION BETWEEN CRITERIA OF MEASUREMENT.

	Trials-Errors	Trials-Time	Errors-Time
RATS			
A—*B*	.48	.03	.92
A—*C*	.34	.15	.87
A—*D*	.76	.76	.94
A—*E*	.83	.88	.76
A—*F*	.67	.74	.93
HUMANS			
A—*B*	—.10	.40	.70
A—*C*	.93	.56	.37
A—*D*	.78	.83	.88

From this table of data, the following comparisons can be made. (1) The correlation is positive in twenty-three of the twenty-four cases. This uniformity indicates the existence of some dependent relation between trials and errors, trials and time, and errors and time as a means of measuring the transfer. (2) The human subjects exhibit the higher values in five of the nine cases of comparison. Whether this is due to chance or represents a general tendency, it is impossible to say at this time. (3) A higher correlation obtains between time and errors than between trials and either of the other two criteria in six of the eight possibilities. But apparently no difference obtains for trials and errors as compared with trials and time. (4) The pair of mazes A-*D* gives the highest values in five of the six cases. No uniform difference obtains between A-*B* and A-*C*.

B. Dependence of Transfer upon the Character of the First Problem.

The object of the second experiment is to determine the dependence of the degree of transfer upon the nature of the first maze.

The possibility of the degree of transfer depending upon either the first or second learned problem has been previously mentioned. This was illustrated from the discussion about the Classics. The student may learn mathematics, history and science first and then study Latin; the degree of transfer in this instance might depend, not upon Latin, but upon the previously mastered subject. This is the type of problem to be discussed in this section of our paper.

In order to test experimentally such a proposition as was raised in the perceding paragraph, one factor must be kept constant. Maze A is again the constant activity. One group of subjects first learned Maze B and then was transferred to Maze A. Another group was transferred from C to A, one from D to A, a fourth from E to A, and a fifth from F to A. The varying factor in this situation is the first learned maze; the second acquired problem is kept constant for all of the groups. If the degree of transfer is wholly a function of the second or constant activity, the variations should be only such as can be accounted for in terms of group, or mere chance differences. Should marked variations obtain in the degree of transfer, it can be said that these are due in part to the differences in the character of the first learned problem.

The amount of transfer was measured in the manner described in the preceding topic, viz., by the comparison of the transferred learning with the original mastery of the same maze. A control group for Maze A is therefore necessary, and this group contained 54 rats and 21 humans. The computations were figured in the same manner as described above for the three criteria of trials, errors, and time.

Table 8 presents the results in the absolute terms of group averages. These group averages, together with the average deviations, for the original and the transferred learning are

TABLE 8. COMPARATIVE RECORDS OF ORIGINAL AND TRANSFERRED LEARNING.

	Trials	Errors	Time
	RATS		
A	38.9±12.9	205.9± 60.9	1782.4±821.8
B—*A*	7.7± 6.6	9.7± 9.5	221.3±212.5
Sav.	31.2	196.2	1561.1
C—*A*	19.3± 8.9	76.3± 28.6	487.1±218.6
Sav.	19.6	129.6	1295.3
D—*A*	23.7±11.7	58.8± 39.2	457. ±199.7
Sav.	15.2	147.1	1325.4
E—*A*	22.5±11.6	82.3± 36.8	651.5±318.
Sav.	16.4	123.6	1130.9
F—*A*	35.1±10.9	99.2± 24.9	704.7±254.4
Sav.	3.8	106.7	1077.7
	HUMANS		
A	24.3± 9.7	231.2±111.6	970.8±388.2
B—*A*	5. ± 4.8	5.8± 5.7	118.6±104.7
Sav.	19.3	225.4	852.2
C—*A*	25.5± 8.1	171.7±106.3	670.2±380.8
Sav.	—1.2	59.5	300.6
D—*A*	27.5±10.	128.5± 57.1	524.3±153.8
Sav.	—3.2	102.7	446.5

given for each of the criteria. The letters in the table indicate the records for the several mazes; thus *A* denotes the record for the original learning of that maze, and B-*A* indicates the transferred learning of the same maze. The B, C, D, E, F in connection with A, e. g. C-*A* etc., means that the previous maze experience of the group consisted of the maze shown by that letter. The symbol Sav. refers to the average amount saved for each group and these figures thus measure the transfer effect for each group.

From an examination of the data in this table, we are able to make the following conclusions, which will be illustrated and discussed in order.

1. The nature of the transfer is positive for all five mazes. The above statement is true for twenty-two of the twenty-four

instances of comparison. The two instances that failed to show positive transfer are found in the human records for trials in the transfer from C-*A* and D-*A*, and yet in these two cases a positive transfer obtains in terms of errors and time. In the transfer from C to A a loss of practically 5% is noted by the criterion of trials, and in the transfer from D to A, by the same criterion, a loss of over 13% is observed. The cause of this is not known; it may represent a matter of chance, or it may be a valid instance of negative transfer. In the transfer from C to A the loss is rather small, and a saving of over 40% is shown by the other two criteria, and this fact might argue that chance is responsible. One consideration may be offered, which tends to indicate that this loss is due to an individual peculiarity. In this transferred group, D-*A*, one subject used more trials to learn Maze A than did the other twenty-one subjects. This same person was also the most erratic subject in the original learning of Maze D; he used next to the largest number of trials, made considerably more errors, and consumed much more time than did any of the other subjects. The average deviation for his group in the transferred record D-*A* is larger than in the original learning of A, and this fact, we believe, can be attributed to this individual's record. Judging from these considerations, it appears to us that the results prove, with a high probability, that positive transfer exists in the cases C-*A* and D-*A* with human subjects.

The three possible causes for the differences between the records of the original and the transferred learning, that were suggested in discussing topic A, are equally relevant here. The causal factors may be chance, group differences, or the previous training of the transferred groups. The arguments previously advanced to prove that the differences are real and represent a transfer effect have an equal bearing in this connection. It is noted that the average deviations are rather wide, and this result is due perhaps to the small number of subjects in the various groups. For the data of this table we computed the Probable Difference, and in twenty-one of the twenty-four instances of measurement the actual difference is found to ex-

ceed the probable difference. We have the same situation as regards the matter of consistency; the differences are uniformly lower for the transferred records in twenty-one of the twenty-four instances of measurement. This consistency strengthens the probability, to a high degree, that chance is not responsible for the differences. The groups used in this experiment were secured and mixed as described in the previous experiment, thus eliminating the possibility of the differences being due to group variations. Further the control group is composed of a rather large number of subjects. Every subject that originally learned Maze A during the eight months of the experimentation was utilized in this control group. This fact lessens to a greater degree the possibility that group differences are functioning in any large part. We have thus shown by mathematical calculation and by the matter of consistency, that chance can not be functioning to a significant degree; the possibility of group differences being a large causal factor is eliminated by our method of securing and mixing the subjects of the various groups. Hence, we again believe, beyond doubt, that the nature of the transfer is positive.

In this, as in the former experiment, the transfer effect remained positive, despite our efforts to so arrange the maze patterns in such a way as to produce a negative effect. These relations between the maze patterns have been described and illustrated. The transfer from C to A reverses the direction of travel; D and A involve a new arrangement of cul de sacs. E and A represent a transfer from a simple to a difficult pattern, while F to A involves an increase in the length of the true pathway and a new arrangement of cul de sacs.

2. The degree of transfer in this experiment is in part a function of the first problem.

As we have previously stated, the second maze is the constant activity, while the first maze is different for each pair. If the degree of transfer is a function of the constant factor, the differences should not vary beyond what can reasonably be attributed to mere chance. On the other hand, if the degree of transfer varies beyond the possibility of mere chance differences, this re-

sult must be regarded as a function of the first or varying activity.

By an inspection of Table 8, it will be observed that the amount saved in absolute terms varies considerably in the five cases with the rats and in the three cases with the human subjects. The records of the rats vary by trials from 3.8 to 31.2, and those of the humans from —3.2 to 19.3. For errors rats have a range in the saving varying from 106.7 to 196.2, and the humans from 59.5 to 225.4. In the time records there exist equally wide variations; those of the rats vary from 1077.7 to 1561.1, and those of the humans from 300.6 to 852.2.

The previous discussion (page 24) of the significance of such wide variations in the degree of transfer is in point here. We believe that the possibilities are rather remote that mere chance would cause such a wide range of variations as noted. By comparing the amounts saved (Table 7) with the figures representing the original mastery of the five mazes (Table 1), it will be noted that the two sets of data are roughly proportionate. For example, the largest saving in trials for the rats was obtained in the transfer from B and this maze required the greatest number of trials for its mastery. Likewise C mediated the next highest amount of saving in trials and this maze was also second as to difficulty of mastery. The dependence of the amount saved in each case upon the difficulty of the first maze is best demonstrated by computing the correlation between the two sets of data. By referring to the correlation values in Table 9 below, it is observed that a positive correlation exists for trials, errors, and time, and for both humans and rats. This fact proves that as changes in the character of the first maze were made, corresponding changes in the degree of transfer occurred. Hence, we believe that we are justified in concluding that the varying degree in the transfer effect is in part a function of the varying activity, viz. the first learned problem.

3. A positive correlation is found to exist between the degree of transfer and the difficulty of the first problem.

The values of Table 9 represent the correlation between the amounts saved in the transfer to Maze A and the amounts of

effort, figured by trials, errors, and time, expended in the original mastery of Mazes B, C, D, E, and F. The ranking method of computation was employed.

TABLE 9. CORRELATION BETWEEN DEGREE OF TRANSFER AND DIFFICULTY OF FIRST PROBLEM.

	Trials	Errors	Time
Rats	.60	.60	.50
Humans	.90	1.00	1.00

On examining Table 9, it is noted that the correlations are positive in every instance for both humans and rats. The data between which the correlation was computed in each case were so few in number that but little reliance can be placed upon the validity of any one of the correlation values. In estimating the validity of these values, the uniformity of positive results must be emphasized. A positive correlation was secured in each of the six comparisons, and this consistency increases the probability of any single value manyfold. The validity of the values can not be attacked because a perfect correlation was not obtained in each case, for such is not to be expected as we demonstrated in our first experiment, that the amount of transfer is also correlated with the difficulty of the second of each pair of mazes.

The correlation values are noticeably higher for the human subjects than for the rats. It is hardly possible to determine whether this difference is due to chance, or to some difference between human and animal organisms.

4. A positive correlation is found between the amount of transfer and the degree of similarity of the two maze patterns.

TABLE 10. CORRELATION BETWEEN AMOUNT SAVED IN TRANSFER AND SIMILARITY OF MAZES.

	Trials	Errors	Time
Similarity by Order of Merit.			
Rats	.10	.60	.60
Humans	.50	1.00	1.00
Similarity in Terms of Difficulty of Mastery.			
Rats	.10	.80	.00
Humans	.50	.50	1.00

The degree of similarity between any two maze patterns was

measured by the same two methods as were used in the first experiment. In fact the rankings as to similarity are the same in both experiments. The correlation values are given in Table 10.

A positive value was secured in 11 of the 12 comparisons, and these positive values range from .10 to 1.00. The validity of our conclusion must again depend upon the uniformity of the results. The values are higher for the humans in five of the six cases, and in general errors and time give higher values than does the criterion of trials. Since the rankings as to similarity are the same as in the first experiment, we may repeat the former statement that some degree of positive correlation obtains between the two methods of estimating the similarity.

5. A comparison of human and rat results reveals an essential similarity. No radical difference can be inferred from these data.

Both classes of subjects exhibit a positive transfer. Two exceptions are to be found in the human records, but these are probably due to chance or individual peculiarity. In this experiment the rats exhibited the greater amount of transfer in eight of the nine instances of comparison. The single exception refers to the saving in errors due to the transfer from Maze B to A. When the amount saved is stated in terms of its percentage relation to the records representing the mastery of the first maze, the rats again manifest the greater effect from their previous tuition in seven of the nine comparisons. While the rats were able to utilize their previous training to a greater degree than the humans, yet that maze which gave the highest transfer for the rats also yielded the highest value for the humans. On the other hand the lowest values for both humans and rats were secured from the same maze. A perfect positive correlation obtained for each of the three criteria, and when the transfer is stated in both absolute and relative terms.

6. The results indicate a positive correlation between any two of the three criteria of measurement.

As in the previous instance of determining such a correlation, we have computed the values from the records of the individuals

in each of the transferred groups. The ranking method of correlation was employed, and Table 11 presents the results upon which the above conclusion is made.

Comparisons, such as were made in the first experiment, can also be made from the data in this table. (1) There is a positive value in all of the twenty-four cases, and this again indicates the existence of some dependent relation between any two of the three criteria as a means of measuring the transfer. (2) The human subjects exhibit higher values in eight of the nine comparisons. We are unable at this point to determine whether this is due to chance, or whether a general tendency is present. (3) Little uniformity obtains as to the matter of higher values between errors and time and either of the other two criteria. Likewise, there is a lack of uniformity in comparing the results for trials and errors, and trials and time. (4) No definite statement can be made as to uniformly higher values for any one pair of mazes.

TABLE 11. CORRELATION BETWEEN CRITERIA OF MEASUREMENT.

	Trials-Errors	Trials-Time	Errors-Time
RATS			
B—*A*	.78	.98	.80
C—*A*	.61	.67	.75
D—*A*	.97	.97	.93
E—*A*	.95	.55	.62
F—*A*	.48	.88	.29
HUMANS			
B—*A*	1.00	1.00	1.00
C—*A*	.83	.83	1.00
D—*A*	.99	.90	.95

C. DEPENDENCE OF AMOUNT SAVED UPON DIRECTION OF TRANSFER.

The purpose of this section is to determine whether or not the amount saved is in part a function of the direction of transfer between any pair of mazes.

The problem is readily stated in terms of mazes. In one case the transfer is from A to B, while a second group is transferred from B to A. The same pair of mazes is employed in both tests; the experiments differ only in what we have termed the direction

of the transfer. If the amount saved is different for the two cases, the direction of the transfer must account for the result. If the direction of transfer is not a determining factor, the degree of saving should be practically the same for both experiments.

No new experimental data are required for the solution of this problem, as the first experiment furnishes the results from groups that were transferred from Maze A to each of the other five mazes, while the second experiment gives us the data for the opposite direction of transfer for the same pairs of maze problems. The results from the two previous experiments, found in Tables 1, 2, 7, and 8, are thus utilized and the data so arranged in Tables 12 and 13 as to facilitate a comparison of the amounts saved for the two directions of transfer. Separate comparisons are made for the human and rat subjects, for each of the five pairs of mazes, and for each of the three criteria of measurement. Table 12 states the amounts saved due to transfer in absolute terms, while in Table 13 a comparison is made of the saving stated in relative or percentage terms. The symbol A-B means that the subjects were transferred from A to B, while B-A refers to the opposite direction of transfer for the same pair of mazes. The symbol Dif. indicates the difference in the amounts saved in the two directions of transfer.

1. The direction of transfer is in part a deciding factor in determining the degree of transfer.

The differences between the two sets of results may be due to group peculiarities, chance, or the direction of transfer. The possible functioning of group peculiarities has been obviated by our method of group selection. While differences exist for all twenty-four cases of comparison, yet such a result would naturally be expected even though chance were the only factor operating. Neither are the differences in the majority of the cases large enough to exclude the possibility of chance. The influence of the direction of transfer in mediating the differential results is proven by the fact that the differences are a function of the degree of similarity of the various pairs of mazes. That pair of mazes possessing the highest degree of

similarity yields the smallest difference of saving when the direction of transfer is reversed, while the largest difference of saving tends to obtain for the most dissimilar pair of mazes. The size of the differences for the various pairs of mazes is thus not entirely a matter of chance; it depends to a slight extent upon the degree of similarity of the maze patterns. To prove this relationship, we have computed the correlation between the size of the differences and the degrees of similarity of the various pairs of mazes. From the data of Table 12, we ranked the pairs in the order of increasing values of differential results, and correlated this order with those representing their degree of

TABLE 12. COMPARATIVE AMOUNT SAVED FOR TWO DIRECTIONS OF TRANSFER.

	Trials	Errors	Time
RATS			
A—*B*	43.3	192.2	2068.1
B—*A*	31.2	196.2	1561.1
Dif.	12.1	4.0	507.0
A—*C*	27.4	109.2	1037.2
C—*A*	19.6	129.6	1295.3
Dif.	7.8	20.4	258.1
A—*D*	11.5	122.4	2511.1
D—*A*	15.2	147.1	1325.4
Dif.	3.7	24.7	1185.7
A—*E*	.9	10.4	135.4
E—*A*	16.4	123.6	1130.9
Dif.	15.5	113.2	995.5
A—*F*	17.6	54.7	719.1
F—*A*	3.8	106.7	1077.7
Dif.	13.8	52.0	358.6
HUMANS			
A—*B*	22.8	252.8	1016.6
B—*A*	19.3	225.4	852.2
Dif.	3.5	27.4	164.4
A—*C*	7.5	26.9	214.9
C—*A*	—1.2	59.5	300.6
Dif.	8.7	32.6	85.7
A—*D*	6.0	192.0	686.3
D—*A*	—3.2	102.7	446.3
Dif.	9.2	89.3	239.8

similarity as determined by the two methods described in the first experiment—similarity of difficulty, and similarity of maze patterns. For the rat records, positive values of .30, 1.00, and .20 were secured for trials, errors, and time, respectively when the degree of similarity was measured in terms of difficulty of mastery.

TABLE 13. COMPARATIVE PERCENTAGES SAVED FOR TWO DIRECTIONS OF TRANSFER.

	Trials	Errors	Time
RATS			
A—*B*	77.08	85.81	83.77
B—*A*	80.11	95.27	87.58
Dif.	3.03	9.46	3.81
A—*C*	57.85	46.10	34.94
C—*A*	50.38	62.94	72.67
Dif.	7.47	16.84	37.73
A—*D*	69.02	79.71	90.42
D—*A*	39.14	71.43	74.36
Dif.	29.88	8.28	16.06
A—*E*	19.91	54.63	63.40
E—*A*	42.12	60.03	63.44
Dif.	22.21	5.40	.04
A—*F*	63.01	42.78	59.44
F—*A*	9.59	51.81	60.46
Dif.	53.42	9.03	1.02
HUMANS			
A—*B*	67.86	88.64	87.18
B—*A*	79.41	97.49	87.78
Dif.	11.35	8.85	.60
A—*C*	19.74	20.20	29.18
C—*A*	—4.98	25.74	30.97
Dif.	24.72	5.54	1.79
A—*D*	51.98	94.58	88.73
D—*A*	—13.21	44.42	45.99
Dif.	65.19	50.16	42.74

The corresponding values for the human subjects were .50, —.50, and —.50. The mazes were also ranked as to differential results by taking an average of the values for the three criteria, and correlation values of .67 and .50 were secured for the rat and human subjects respectively. The differential results were also

correlated with the degree of similarity determined by the method of the 'order of merit,' and the following values were obtained: rats, .20, .40, and —.10 for trials, errors, and time respectively; the corresponding values for humans were .50, .50, and —.50; when the order of differential results was determined by averaging the values for the three criteria, values of .10 and .50 were secured for the rats and humans respectively. The mazes were again ranked in order of increasing values of the differential results as given in percentage terms in Table 13. This system of values was likewise correlated with the degree of similarity of the maze patterns. These correlation values were practically identical with those above and so need not be given. It is noted that small positive values predominate; positive values were secured in 14 of the 17 computations. The validity of our proposition must depend upon the consistency with which these positive values were secured. To our mind these data prove that the direction of the transfer between any pair of mazes exerts some slight effect upon the resulting degree of saving.

2. The relative amount of retracing differs according to the direction of transfer.

The data supporting this conclusion are found in Table 14. We recorded separately the errors due to entrances into cul de sacs, and returns over the true path. The table gives in percentage terms the number of retracing errors relative to the total number of errors made in the mastering of each maze. For example, in the mastery of B by the rats, 41.7% of the total number of errors was due to retracing. The corresponding value for the transferred learning of B is 60.7%. In this case the transfer increased the relative amount of retracing, and this fact is denoted in the table by the positive sign plus placed after the value 60.7%. A different result was obtained for the opposite direction of transfer. The percentage values are 40.3 and 27.8 respectively for the original and the transferred mastery of A. Transfer in the direction of B-A thus decreased the relative number of errors due to retracing, and this fact is indicated in the table by the minus sign placed after the value 27.8. Direction of transfer thus operates differently for the mazes A

and B; one direction increases the relative amount of retracing while the other increases it. An inspection of the positive and minus signs for the various pairs of mazes reveals the fact that this differential effect due to the direction of transfer obtains for four of the five comparisons of rat records and for two of the three cases for the human subjects.

TABLE 14. PERCENTAGE OF ERRORS DUE TO RETRACING.

Rats		Humans	
B 41.7	A 40.3	B 65.8	A 69.3
A-B 60.7+	B-A 27.8—	A-B 59.8—	B-A 27.6—
C 66.7	A 40.3	C 48.4	A 69.3
A-C 76.3+	C-A 38.3—	A-C 44.2—	C-A 69.6+
D 71.5	A 40.3	D 60.3	A 69.3
A-D 75.3+	D-A 17.2—	A-D 60.9+	D-A 64.8—
E 54.7	A 40.3		
A-E 41.8—	E-A 36.1—		
F 33.7	A 40.3		
A-F 35.1+	F-A 30.1—		

3. The influence of the direction of the transfer is essentially identical for human and animal subjects.

The correlation values given above (page 43 f.) are essentially similar for the two types of subjects. It will be noted in Table 12 that the direction B-A gives for both humans and rats a smaller saving in trials than does the reverse direction of A-B. In six of the nine possible comparisons of this sort, those directions giving the greater saving for the rats also give the larger values for the human subjects. This correlation is perfect when the percentage values of Table 13 are utilized in the comparison. Evidently the conditions governing transfer are essentially the same for the two types of organism.

D. LOCUS OF THE TRANSFER IN THE LEARNING CURVE.

Our purpose here is to compare the original and transferred learning curves, thus enabling us to discover what part of the learning curve is affected by the transfer.

Transfer reduces the total amount of time and the total number of errors in learning a maze. This reduction may be accom-

plished in one of three ways. (1) The saving may be distributed proportionately among the various trials. In this case the curves for the transferred and the original learning would be similar in form but different only in height. For example, the number of errors made in each trial in transfer may be one half of that made in the original mastery of the same maze. (2) The two curves may be identical in height and form for the first trials and differ only in the final trials. In this case the saving due to transfer would be confined to the final stages of mastery, and the curve for the transferred learning would exhibit a sudden final drop. (3) The saving due to transfer may also be confined to the early trials. In this instance, the curve for the transfer would begin with much lower values than the curve for the original mastery, decrease much more gradually at first, and finally become identical with that for original learning in the last stages of mastery. The initial drop characteristic of the normal maze curve would thus be absent in the transfer curve. The term 'locus of transfer' will be used to represent that group of trials in which the transfer effect is mainly manifested.

The locus of transfer is on the average confined to the first five trials. Subjects transferred to any maze are saved the equivalent of the first five trials of effort; they begin the problem at an advanced stage of mastery and complete it in a normal manner. The transferred curves thus do not exhibit that sharp initial drop characteristic of normal curves.

This general conclusion is illustrated by typical data found in Figures 7 and 8. To the left of each figure are found the error and time curves representing the progress of learning for the first five trials of the original mastery of the various mazes. To the right is placed the initial part of the corresponding curves for transferred learning. It will be noted that the transferred curves begin at a level closely approximating that reached by the curves for the original learning at the fifth trial. These particular curves have been selected for purposes of illustration, because they represent not only the average but the most frequent in the sixteen cases of comparison. Twelve of the sixteen cases closely approximate the conditions represented by these figures.

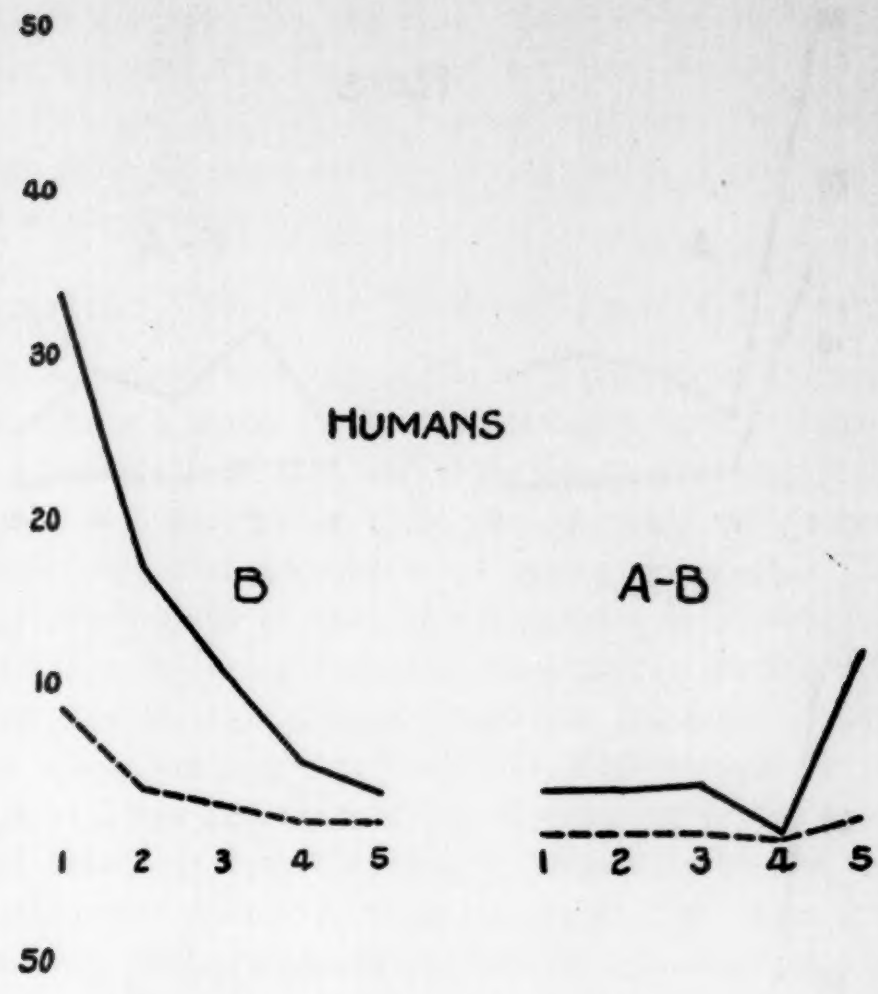
50
40
30
HUMANS
20
B
A-B
10
1 2 3 4 5
1 2 3 4 5
50
40
30
RATS
20
B
A-B
10
1 2 3 4 5 1 2 3 4 5

FIGURE 7.

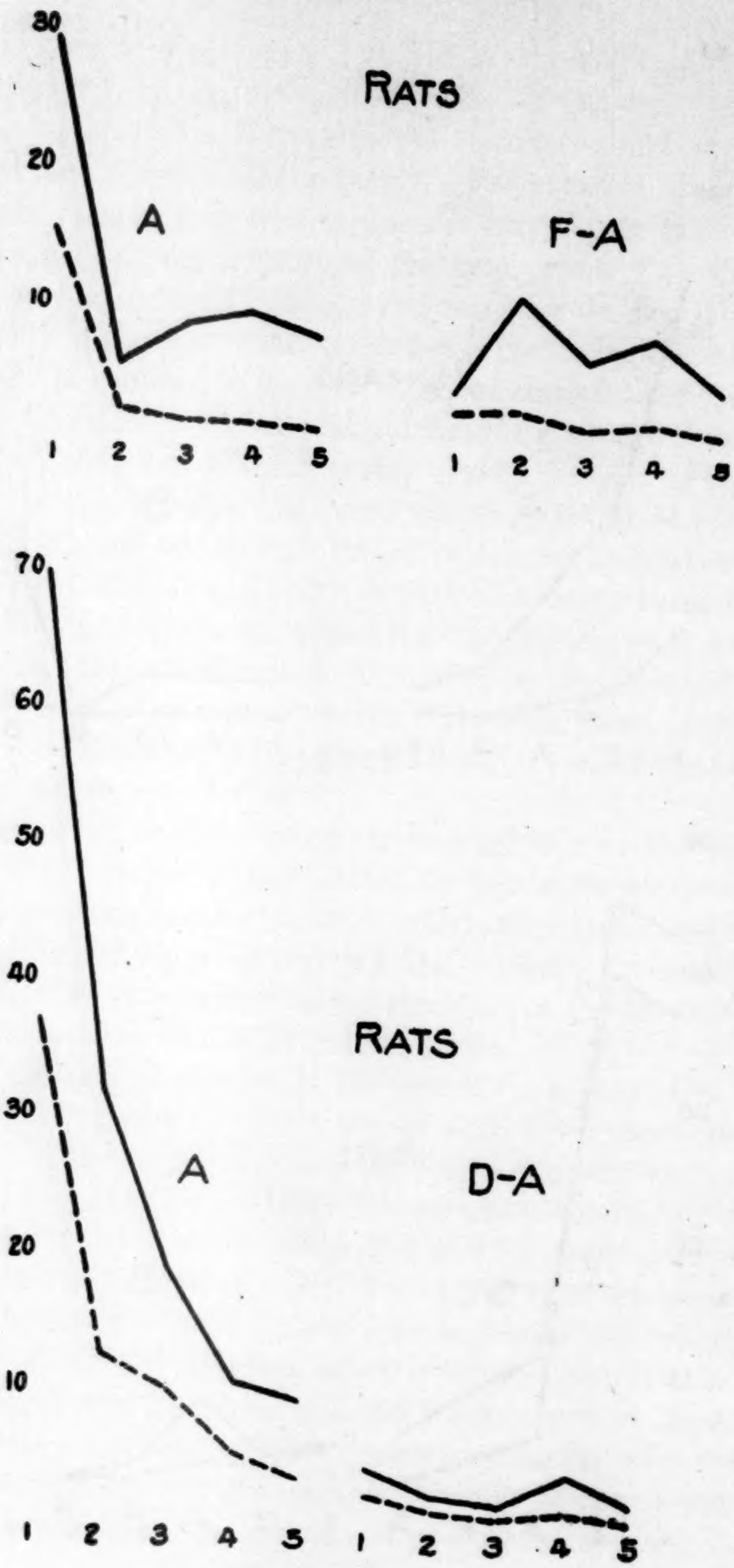
RATS
A
F-A
30
20
10
1 2 3 4 5
1 2 3 4 5
70
60
50
40
30
20
10
RATS
A
D-A
1 2 3 4 5 1 2 3 4 5

FIGURE 8.

Four cases diverge from the type. In C-A for the humans and A-F for the rats, the two curves are more nearly identical in form. B-A and A-D for the humans represent the opposite divergence from the type; here the saving due to transfer is equivalent to seven or eight trials.

E. Selective Effect of Transfer upon Types of Error.

Transfer effects a saving in the total number of errors necessary to master a maze. These errors comprise two sorts—those due to entering cul de sacs, and those due to retracing in the true pathway. We have listed these two types of error separately, and have computed the degree of saving for each. This was done by dividing the number of errors made in the original mastery of the maze into the number occurring in the transfer; this quotient was then subtracted from one hundred. These percentage values are found in Table 15. For example the transfer from A to B reduced the number of retracing errors by 79.4%, and the cul de sac errors by 90.4%. Transfer in this case was more efficacious upon the cul de sac errors than upon those due to retracing. The purpose of this section is to determine whether transfer has a greater effect upon one type of error than upon the other.

Transfer on the whole exerts a slightly greater effect upon retracing. It tends to minimize the tendency to retrace relatively more than it does the tendency to enter cul de sacs.

The above conclusion is evident from an inspection of the data in Table 15. The percentage values are larger in 11 of the 16 cases of comparison. There is no essential difference between humans and animals as to the selective effect. Nor does the differential effect depend upon the direction of the transfer. Transfer is more effective upon retracing in some pairs of mazes than in others, but this difference of effect with the various pairs of mazes is not correlated with their similarity; neither is it correlated with the difficulty of the mazes measured by the number of errors involved in either original or transferred learning.

TABLE 15. GIVING THE PERCENTAGE OF DECREASE DUE TO TRANSFER IN NUMBER OF RETRACING AND CUL DE SAC ERRORS RESPECTIVELY.

	Retracing	Cul de sac
RATS		
A-B	79.4	90.4
A-C	38.0	61.5
A-D	78.8	82.2
A-E	65.4	41.9
A-F	40.2	45.0
B-A	96.8	94.3
C-A	64.9	61.7
D-A	87.9	60.4
E-A	64.3	57.2
F-A	63.8	43.8
HUMANS		
A-B	89.7	86.7
A-C	28.9	11.5
A-D	96.1	87.0
B-A	99.1	94.1
C-A	25.5	26.3
D-A	48.7	36.2

In those mazes in which the greatest saving of cul de sac errors is exhibited, transfer also tends to give the greatest saving in retracing.

The evidence to support this conclusion was determined by correlating the two sets of values given in Table 15. The results were .60 and .90 for the rats, and 1.00 and 1.00 for the humans. These correlation values mean that in measuring the degree of transfer between various pairs of mazes, one can utilize the saving in retracing, or the saving in cul de sac errors, or the saving in the total number of errors, as we have done, without materially changing the results.

F. SUMMARY.

Upon the basis of the foregoing study of transfer, we have been able to make the following conclusions.

1. The nature of the transfer is positive. The learning of one maze has a beneficial effect in the mastery of a subsequent maze situation. We tested the nature of the transfer for both

directions between five pairs of mazes with rats, and three pairs with human subjects. We thus secured sixteen separate tests of the nature of the transfer. In all of the sixteen cases the result was positive. We also used three criteria of measurement —trials, errors, time—thereby obtaining 48 separate measurements of the transfer. In 46 of these measurements the average for the test group was smaller than that for the control group, thus indicating a positive transfer. It might be argued that the difference between the original and transferred learning records was due to chance or group differences. That the differences were not due to chance, but to the positive transfer, was proven by the fact that the actual difference was found to exceed the probable difference in 45 of the 48 comparisons. Further, the consistency with which the differences occurred lessened the probability manyfold of chance being a primary causal factor. Our method of securing the subjects and of selecting the groups eliminated the probability of group differences functioning to a significant degree. Hence we conclude that the primary causal factor determining the differences between the original and transferred learning records is not chance or group differences, but the positive nature of the transfer.

In the 48 measurements of the transfer two exceptions occurred to the positive results. These were found with the human subjects by the criterion of trials. In these two instances we have shown that the loss was probably due to an individual peculiarity. Furthermore, in these two cases the transfer as measured by errors and time was of a strong positive character. While we admit the possibility that these two exceptions were caused by negative transfer, we believe that the greater probability favors the transfer being of a positive nature, and that we are justified in concluding that the transfer was positive in the sixteen tests.

The transfer remained positive despite our efforts to produce conditions that would give a negative result. In the first pair of mazes, A and B, the construction was so designed as to give a high degree of positive transfer, and the results verified our expectations. The purpose in designing the other four pairs of mazes was the desire to secure conditions that would produce

a negative effect, and in every instance we were disappointed in the outcome. We do not conclude that it is impossible to demonstrate a negative transfer effect between two pairs of mazes. On the contrary, we admit such a possibility. However, for the conditions maintained in this experiment, the transfer was of a positive nature.

2. Transfer is a composite process consisting of both positive and negative elements, and the total result is determined by the predominance of the one or the other of these elements. The total effect was positive although the presence of a negative element was shown to exist. Maze F was designed in relation to Maze A in such a manner that it was possible for us to determine whether certain habits acquired in A exerted a negative effect in the subsequent mastery of F. Subjects with the Maze A experience had greater difficulty in eliminating the tendency to enter section 6-10 in F, entered this section much more frequently, and made many more errors in this section, than did those subjects without such an experience. This evidence, we believe, proves the existence of a negative element in the transferred learning of Maze F. In order to produce a negative transfer effect, conditions will have to be arranged wherein the negative element predominates.

3. The degree of transfer is determined by a number of factors.

(1) It is in part a function of the nature of the second activity. The first activity was constant for all of the groups in the first experiment, while the second problem varied with each group. The divergence of the results was wide enough to indicate that the activity set up in the second maze situation was in part a causal factor. The proof to substantiate this conclusion was found in the fact that the relative amounts saved in the five cases was correlated with the relative difficulty of the second mazes as measured by the original records of mastery. A positive correlation was found in all six cases of comparison.

(2) The activities acquired in the first problem determine in part the degree of the transfer. In this instance the second maze was constant, and the varying activity was the first problem.

This conclusion was proven by the fact that the amounts saved and the original learning records were roughly proportionate, and by the consistency of the positive values found in determining the correlation between the degree of transfer and the difficulty of the first problem.

(3) The degree of transfer is dependent in part upon the degree of similarity of two maze patterns. The evidence for this conclusion was determined by computing the correlation between the degree of transfer the similarity of the five pairs of mazes. Two methods were utilized in securing these correlation values—the order of merit, and difficulty of mastery. This gave twelve values for each experiment. In the first case all twelve values were positive, while in the second 11 of the 12 values were positive. The significant thing here was the consistency with which positive values occurred. This fact enhanced their validity manyfold, and, we believe, amply justified the above conclusion.

(4) The amount saved is determined in part by the direction of the transfer. Differences were found to exist for the opposite directions of transfer, stated in both absolute and relative terms. The influence of the direction of transfer in mediating the differential results was proven by the fact that the differences are a function of the degree of similarity of the various pairs of mazes. That pair of mazes most similar yielded the smallest difference of saving when the direction of transfer was reversed, while the largest difference of saving tended to obtain for the most dissimilar pair of mazes. This relationship was tested by computing the correlation between the size of the differences and the similarity of the various pairs of mazes. Seventeen values were obtained, and 14 of these were positive. We believe, that the consistency with which positive values occurred proves the above conclusion.

4. The laws and conditions of transfer are essentially identical for the two types of organism employed in this study.

The transfer was positive for both human and rat subjects. This was the result in the six cases of comparison when the maze patterns were identical, and the conditions of experimentation highly similar. The results were the same for the two types

of subjects in two respects. First: That pair of mazes which induced the greatest amount of saving for the rats had a like effect with human subjects; mazes which gave the least results with the human subjects produced a similar effect with the rats. This comparison was proven by determining the correlation values in absolute and relative terms. Of the nine values resulting seven were perfect and two were plus fifty. Second: The influence of the direction of the transfer was essentially identical for humans and rats. That direction which gave the greater saving for the rats also gave the larger values for the human subjects in six of the nine possible comparisons. When the correlations were computed in relative terms all of the values were perfect. While the total result was similar for rat and human subjects, there was one difference noted. The rats evidenced more ability in utilizing a previous maze experience in a new situation than did the human subjects. The difference favored the rats to a pronounced degree in all three pairs of mazes in both experiments when measured by trials and time, and whether stated in relative or absolute terms. Measured by the criterion of errors, the human subjects manifested the greater saving. A possible explanation of the differences was offered in the character of the previous training. Upon the total evidence, we concluded that human and animal organization are highly similar so far as the laws and conditions of transfer are concerned; that the processes involved were highly similar, and that no factors, such as rational activities peculiar to the human subjects, were functioning in the process of transfer.

5. A positive correlation was found between any two of the three criteria of measurement. There were 24 values in each experiment; in the first 23 of these were positive, and in the second all were positive. This indicates that some dependent relation exists between trials and errors, trials and time, and errors and time as a means of measuring the transfer. In the first experiment higher values predominated between time and errors, but in the second experiment there was little uniformity as to higher values. This lack of uniformity prevented us from drawing any conclusion as to the greater validity of any two of the three criteria of measurement.

6. The locus of transfer was on the average confined to the first five trials. The subjects were saved the equivalent of the first five trials of effort. Twelve of the sixteen comparisons approximated the average. The exceptions ranged in the amount saved from two to eight trials. This means that in the transferred learning the subjects attacked the new problem at an advanced stage, varying from the second to the eighth trial, and completed the mastery in a normal manner.

7. Transfer exerted some selective effect upon the types of error. The tendency to retrace the true pathway is minimized relatively more than the tendency to enter cul de sacs. This conclusion was supported by the fact that when the reduction in the two types of error was stated in relative terms, the values representing retracing were larger in 11 of the 16 cases of comparison. This differential effect does not seem to depend upon the direction of the transfer, the difficulty of the mazes, nor upon the degree of similarity of a pair of mazes. These facts indicate that the selective effect upon retracing represents some general transfer effect applicable to all maze conditions.

It was further proven that that pair of mazes which produced the greatest or the least effect upon retracing had a similar effect upon cul de sacs. This was determined by correlating the two sets of data, and high positive values resulted in every case. This means that the general effect of the transfer was the same for both types of error; that pair of mazes which gave the greatest reduction in retrace errors also produced the greatest effect upon cul de sac errors, but the effect was greater upon retracing. Thus we concluded that one could utilize the saving in retracing, cul de sac errors, or both without materially changing the results.

G. Theoretical Discussion.

It is not our purpose to formulate a theory of transfer. We shall confine our discussion to a consideration of two of the prevalent theories in relation to our results.

Bagley[1] maintains that transfer depends upon the development of ideals. Habits of neatness acquired in one school subject

[1] W. C. Bagley, The Educative Process, p. 208.

will transfer to other school subjects only in so far as an ideal of neatness has been inculcated. An ideal in this sense implies some sort of ideational purpose, and to my mind the theory indicates the doctrine that transfer can occur only on an ideational level. This negative aspect of the theory is controverted by the data of this paper. Our facts prove rather conclusively that a high degree of positive transfer can occur on a purely sensori-motor level. Transfer was manifested by the rats, and it is generally presumed that such organisms do not possess ideational powers. Furthermore, the rats exhibited a greater degree of positive transfer than did the human subjects. If transfer is mediated only by ideational activities, we are forced to assume that human beings are inferior to rats in intellectual capacity, at least so far as the maze situation is concerned. That ideals were not an effective factor in our experiments is proven by the fact none of the human subjects were previously aware that they were to be transferred from one maze to another, while many of the subjects remained in entire ignorance of the fact that a new maze problem had been substituted in the course of the experiment.

Thorndike's theory[2] postulates that transfer occurs between two activities only when these activities possess identical neural elements or bonds of connection, and that the degree of transfer is proportional to the degree of identity of the bonds. This theory, as first stated, would not permit the existence of any negative transfer effect. The existence of negative transfer has been demonstrated by several experiments, and our results further prove that the total transfer effect between any complex set of activities is a composite affair consisting of both positive and negative elements. Poffenberger[3] in a recent Columbia study, with the probable approval of Thorndike, has modified the theory so as to logically include the negative factor. He states that transfer occurs when there is at least a partial identity of bonds. When the bonds established in the first activity are broken in the acquisition of the second act, negative transfer results. When

[2] Thorndike; op. cit.

[3] Poffenberger: The Influence of Improvement in One Single Mental Process upon Other Related Processes. Jr. Ed. Psych. Vol. 6.

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the bonds remain unbroken and are utilized in the second activity, positive results are secured. This theory possesses a great deal of a priori plausibility. Our conclusion that the degree of transfer is in part a function of the degree of similarity of the two maze patterns would seem on first thought to confirm this theory. Our conclusion that the degree of transfer is dependent to some extent upon the direction of transfer would likewise militate against the theory, for logically the partial identity of neural bonds possessed by two sets of activities should be independent of their temporal order. However, we wish to maintain that neither of the above conclusions can be regarded as constituting either a refutation or a confirmation of the theory. It would be rather ridiculous to assert that any two sensori-motor activities must possess a degree of neural identity proportionate to the relative amount of effort expended in their acquisition. Theoretically one might acquire two activities totally isolated in the nervous system whose acquisition involved equal amounts of effort. Objective similarity of maze patterns does not necessarily mean a subjective similarity of the neural activities involved in their mastery. To my mind, herein lies the weakness of the Thorndike theory. Its validity can never be adequately tested. Any general agreement as to the degree of neural identity between any two complex problems is impossible. One can explain any fact of transfer on this basis, for all that is necessary is to assume the appropriate relationship between the nervous activities, and naturally it is practically impossible to disprove this particular assumption. Any theory or any explanation of the laws of transfer should possess some diagnostic value. One should be able to predict to some extent the degree of transfer to be obtained between any two activities. Thorndike's theory is defective in this respect.

Our facts indicate that transfer is to a large extent a function of the particular relationship existing between the two activities. A determination of the laws and conditions of this phenomenon must involve a thorough and complete analysis and definition of the essential relations obtaining between any two activities. This suggests that such complex activities as are involved in

the mastery of a maze situation constitute a poor medium for any comprehensive analysis of transfer. Experiments must be devised by the results of which we will be able to diagnose the relations between the two activities; such as keeping the reactions similar but varying the stimulus, or keeping the stimulus constant and varying the reactions. The problem is to simplify the situation and isolate and control the elements so as to ultimately analyze the existing relationships.

III. RETROACTION

A. Retroactive Effect of a Certain Activity upon Various Other Activities.

The first experiment concerns the retroactive effect which the mastery of Maze A may exert upon the retention of Mazes B, C, D, E, or F. The questions at issue are the existence and nature of retroaction and its dependence upon the character of the habit affected. Two groups of subjects, a test and a control group, are necessary for each of the five pairs of mazes. In the test experiment, each of five groups of subjects learns one of the mazes B, C, D, E, and F; all are then transferred to Maze A; after thirty days mainly devoted to the mastery of A, each group is required to relearn its first maze. This procedure may be represented by the symbol B-A-B. In the control experiment, five groups are utilized and they repeat the above procedure with the exception of the mastery of Maze A; the symbol B—B thus represents the progression of events. The records secured in relearning Maze B in the test experiment represent the disintegration of the Maze B habits due to the thirty day interval plus the retroactive effect of the acquisition of A. The relearning records in the control experiment, however, represent merely the disintegration resulting from the thirty day interval. Any retroactive effect of A on B is thus measured by the difference in the amount of effort expended by the two groups in relearning B.

The test group on Maze B comprised 12 rats and 5 humans, while the control group consisted of 8 rats and 5 humans. On Maze C, both the test and the control group had 9 rats and 5 humans. The test group for Maze D consisted of 7 rats and 6 humans, and the control group had 6 rats and 5 humans. There were 9 and 7 rats respectively in the test and control groups for Maze E. The test group for Maze F consisted of 8 rats, and the control group of 7 rats.

TABLE 16. THE RETROACTIVE EFFECT OF A UPON B.

	B-A-B						RATS	B——B					
	Trials		Errors		Time			Trials		Errors		Time	
Subj.	L.	R.	L.	R.	L.	R.	Subj.	L.	R.	L.	R.	L.	R.
1.	23	3	73	5	916	55	1.	33	0	113	0	1174	0
2.	58	1	460	1	12650	71	2.	49	0	189	0	1211	0
3.	94	4	409	6	7404	80	3.	53	23	205	17	1532	388
4.	40	0	265	0	2708	0	4.	43	8	128	9	1347	135
5.	69	0	238	0	2126	0	5.	73	0	304	0	2106	0
6.	35	0	96	0	1124	0	6.	51	12	204	23	1449	211
7.	49	30	234	37	1430	419	7.	59	12	198	9	1059	164
8.	44	43	191	48	1241	606	8.	48	0	155	0	990	0
9.	104	8	353	7	3204	142							
10.	45	11	209	12	1998	179							
11.	67	3	232	1	1764	57							
12.	88	39	224	36	1940	526							
							HUMANS						
1.	53	11	250	14	1669	322	1.	37	3	1003	13	1791	62
2.	30	0	190	0	903	0	2.	66	0	591	0	1780	0
3.	20	15	64	27	720	211	3.	6	0	36	0	598	0
4.	29	0	235	0	740	0	4.	9	2	116	3	500	29
5.	35	10	80	10	964	175	5.	50	0	287	0	1995	0

TABLE 17. RETROACTIVE EFFECT OF A UPON C.

	C-A-C						RATS	C——C					
	Trials		Errors		Time			Trials		Errors		Time	
Subj.	L.	R.	L.	R.	L.	R.	Subj.	L.	R.	L.	R.	L.	R.
1.	30	1	414	71	12567	696	1.	78	0	167	0	1364	0
2.	57	0	202	0	1189	0	2.	78	1	286	7	2223	48
3.	35	1	188	1	1192	17	3.	78	0	246	0	2083	0
4.	36	3	177	7	1234	36	4.	78	0	281	0	1638	0
5.	74	0	250	0	1604	0	5.	78	1	329	1	4304	31
6.	58	3	475	8	3210	48	6.	46	2	175	23	6815	166
7.	12	2	169	2	264	26	7.	74	0	221	0	1647	0
8.	36	0	202	0	1041	0	8.	71	0	205	0	1907	0
9.	48	0	167	0	1310	0	9.	86	3	308	12	2502	128
							HUMANS						
1.	19	27	99	201	627	737	1.	25	12	174	10	774	114
2.	37	4	38	7	762	59	2.	25	0	121	0	864	0
3.	46	0	208	0	691	0	3.	48	12	188	13	479	13
4.	40	0	73	0	574	0	4.	67	3	147	1	792	13
5.	43	8	171	6	1110	89	5.	30	5	119	7	692	65

TABLE 18. RETROACTIVE EFFECT OF A UPON D.

	D-A-D												
					RATS			D——D					
	Trials		Errors		Time			Trials		Errors		Time	
Subj.	L.	R.	L.	R.	L.	R.	Subj.	L.	R.	L.	R.	L.	R.
1.	13	0	145	0	2943	0	1.	7	0	130	0	1193	0
2.	23	6	122	5	1521	93	2.	19	3	91	7	4094	108
3.	8	0	203	0	3335	0	3.	38	3	144	5	1550	59
4.	31	1	164	1	1912	24	4.	12	5	73	30	1155	309
5.	25	3	394	25	8668	109	5.	11	1	175	5	3617	51
6.	10	4	109	18	2563	153	6.	11	0	163	0	1953	0
7.	9	0	84	0	1601	0							
					HUMANS								
1.	13	15	84	53	600	380	1.	12	0	180	0	1158	0
2.	18	31	207	59	928	293	2.	3	4	67	22	416	328
3.	15	12	207	9	854	111	3.	3	0	5	0	70	0
4.	7	3	37	5	235	50	4.	5	4	90	3	466	51
5.	19	6	1113	17	2764	53	5.	31	0	202	0	903	0
6.	2	7	41	20	115	90							

TABLE 19. RETROACTIVE EFFECT OF A UPON E.

	E-A-E												
					RATS			E——E					
	Trials		Errors		Time			Trials		Errors		Time	
Subj.	L.	R.	L.	R.	L.	R.	Subj.	L.	R.	L.	R.	L.	R.
1.	3	7	17	7	202	74	1.	8	0	36	0	277	0
2.	6	6	26	11	377	104	2.	1	0	14	0	105	0
3.	6	0	34	0	262	0	3.	6	0	6	0	312	0
4.	1	0	19	0	125	0	4.	3	0	7	0	208	0
5.	11	0	31	0	135	0	5.	2	4	7	5	178	50
6.	5	0	19	0	121	0	6.	1	4	14	2	127	26
7.	8	3	18	8	349	36	7.	5	0	20	0	221	0
8.	2	2	15	3	105	28							
9.	2	1	21	2	279	22							

TABLE 20. RETROACTIVE EFFECT OF A UPON F.

	F-A-F												
					RATS			F——F					
	Trials		Errors		Time			Trials		Errors		Time	
Subj.	L.	R.	L.	R.	L.	R.	Subj.	L.	R.	L.	R.	L.	R.
1.	14	16	70	58	491	278	1.	17	1	86	10	816	37
2.	32	0	84	0	591	0	2.	21	5	163	9	1179	48
3.	23	25	159	177	1009	1499	3.	7	4	64	5	1688	27
4.	39	3	165	6	1090	38	4.	12	12	81	21	692	152
5.	35	7	186	86	1145	573	5.	30	5	115	28	909	135
6.	50	14	178	96	1371	704	6.	38	4	146	16	927	215
7.	39	20	139	103	1101	420	7.	34	13	105	16	1456	120
8.	28	26	186	51	3682	346							

The individual relearning records for the test and control groups and for each of the mazes are given in Tables 16 to 20 in the columns marked R. The differences between the two series of relearning records may be due to chance, group peculiarities, or retroaction. The possibility of group peculiarities being a large causal factor, as in the transfer experiment, has been obviated by our method of group selection. Any decision between chance and a retroactive effect presents difficulty because of the high degree of individual variability in the relearning records. Hence for the present we shall refrain from making any conclusions regarding retroaction and content ourselves with mere factual statements concerning the differences between the records of the two groups.

1. The occurrence of any disintegrating effect due to time, or to time and retroaction combined, is an individual matter.

Some individuals were affected and some were not susceptible to the influences. Individual exemptions were present in 14 of the 16 groups of subjects. Out of 82 rats, 31 were not affected, and 11 of the 31 human subjects manifested no disturbance. Of the total number of subjects employed in the experiment 37% suffered no disturbing effect. The human and animal subjects manifested no difference as to their immunity. If retroaction is present, its operations are certainly confined to specific individuals.

2. The individual variability in the relearning records is much greater than in the original mastery of the same maze.

For the purposes of this comparison we have inserted in Tables 16 to 20 the individual records for the original learning of the various mazes. These are found in the columns marked L. The values under L and R thus give the individual learning and relearning records respectively of the various subjects. The validity of our proposition is apparent from an inspection of these data. We computed, however, for each group the averages and the average deviations for the learning and relearning records. Each average deviation is divided by the corresponding average, thus expressing the value of the deviation relative to the average in percentage terms. These various percentile values are given

in Table 21. The columns L and R give the values for learning and relearning respectively. It is to be noted that the relative

TABLE 21. INDIVIDUAL VARIABILITY IN LEARNING AND RELEARNING.

	Test Groups							Control Groups					
	Trials		Errors		Time			Trials		Errors		Time	
Group	L	R	L	R	L	R	Group	L	R	L	R	L	R
RATS													
B-A-B	34	107	33	108	71	95	B—B	16	100	22	100	19	100
C-A-C	34	93	29	136	89	146	C—C	9	110	19	149	45	141
D-A-D	47	100	41	118	49	102	D—D	39	83	24	94	48	92
E-A-E	52	101	24	101	36	97	E—E	60	143	50	133	27	142
F-A-F	25	57	26	58	46	68	F—F	42	55	26	40	27	56
HUMANS													
B-A-B	26	84	45	81	27	80	B—B	62	120	77	122	46	120
C-A-C	17	113	44	157	22	133	C—C	39	70	16	73	15	70
D-A-D	42	58	91	78	53	71	D—D	80	120	60	136	57	133

variability in relearning is the greater in each of the 48 comparisons. On the average the relearning values are at least three times as large as those representing the original learning.

There is no consistent difference as to relearning variability between the human and rat subjects, nor between the control and test experiments. Comparing the variability of mazes, there is but one uniform result of whose validity we may be confident. Maze F gives by far the lowest relearning variability values for all three criteria and for both the test and control groups.

3. There is practically no correlation between the learning and the relearning records.

We ranked the individuals of each group according to their ability in learning as measured by each of the criteria. The same individuals were also ranked as to their ability manifested in relearning the same maze, and the correlation values between the two sets of data were computed. These values are to be found in Table 22. All of the values are extremely small, and but 28 of the 48 values are positive. If any tendency towards a positive correlation be present, it is slight in amount. No significant differences differentiate humans from rats, the control and test groups, nor one maze from another.

TABLE 22. CORRELATION BETWEEN LEARNING AND RELEARNING.

Group	Trials	Errors	Time
RATS			
Test Groups			
B-A-B	.30	—.10	—.03
C-A-C	—.35	.44	.48
D-A-D	.50	.36	.22
E-A-E	.06	—.33	.55
F-A-F	—.37	.08	.41
Control Groups			
B—B	.40	.39	.37
C—C	.33	.37	.85
D—D	.78	—.57	—.07
E—E	.05	.04	—.17
F—F	—.14	.16	—.46
HUMANS			
Test Groups			
B-A-B	—.05	—.32	.38
C-A-C	—.25	—.42	.03
D-A-D	.26	.26	.15
Control Groups			
B—B	—.10	.50	.00
C—C	.08	.70	—.60
D—D	—.22	—.20	—.40

This general result means that individuals making good records in mastering a maze are just as liable as not to do poorly in relearning the same maze. It is thus impossible to predict from the learning records the relative ability of a group of subjects in again mastering the same maze. The individual differences in the relearning tests thus do not represent any permanent differences of individual capacity, nor are they the result of any habits acquired during the original mastery of the maze. The greater individual variability manifested in relearning as opposed to learning (see former section) must thus be due, not to permanent individual peculiarities nor to acquired habits, but to individual differences in susceptibility to the disintegrating influences of intervening conditions. Since the relearning variability of the control group is not greater than that of the test group, it is evident that time and not any possible retroactive effect is primarily the responsible intervening factor.

4. A greater percentage of the subjects in the test series mani-

fested some degree of disintegration of the old habit. This greater effect may be due to retroaction.

This generalization is apparent from the data as tabulated in Table 23. Of the total number of rats used in the test series, 66.7% were disturbed while but 57% were affected in the control series. For the humans the percentages affected are 75 and 53.3 for the test and control series respectively. More rats were affected in the test series for 3 of the 5 mazes, and the same statement is applicable to the humans for 2 of the 3 mazes. On the whole there is a uniform tendency towards a greater susceptibility in the test series.

TABLE 23. PERCENTAGE OF SUBJECTS AFFECTED.

	Rats		Humans	
Group	Test	Control	Test	Control
B	75.0	50.0	60.0	40.0
C	55.5	44.4	60.0	80.0
D	57.0	66.7	100.0	40.0
E	55.5	28.5		
F	87.5	100.0		
Total	66.7	57.0	75.0	53.3

5. The average amount of disintegration for those subjects affected is on the whole somewhat higher in the test series.

The comparative data supporting the above generalization are to be found in Table 24. For the rats the test series gives the higher values in 13 of the 15 cases of comparison. With the humans higher values are found in the test series in all 9 instances of comparison. Considering the values for rats and for humans as single groups, the test series gives the higher values for all three criteria of measurement. The rat values in the test series are the larger in 3 of the 5 mazes, while the human values are higher for all three mazes. In the rat records the differences in favor of the test series are the most pronounced for Maze F. On the whole the humans show more evidence of negative retroaction than do the rats.

6. The percentage of disintegration or loss during the thirty day interval is on the whole somewhat higher in the test series.

Table 25 presents the comparative data in support of the above statement. The test series in the rat records gives the higher

TABLE 24. AVERAGE RELEARNING RECORDS FOR SUBJECTS MANIFESTING DISINTEGRATION.

	Test				Control		
Group	Trials	Errors	Time	Group	Trials	Errors	Time
RATS							
B	15.78	17.00	237.22	B	13.50	14.50	224.50
C	2.00	17.80	164.60	C	1.75	10.75	93.25
D	3.50	12.25	94.75	D	3.00	11.75	131.75
E	3.80	6.20	52.80	E	4.00	3.50	38.00
F	15.85	82.12	552.00	F	7.14	15.00	102.85
Average	8.18	27.07	220.27		5.88	11.10	118.07
HUMANS							
B	12.00	17.00	236.00	B	2.50	8.00	45.50
C	13.00	71.33	295.00	C	8.00	7.75	63.75
D	12.33	27.17	162.83	D	4.00	12.50	37.90
Average	12.44	38.50	231.27		4.83	7.41	49.05

values in 12 of the 15 cases of comparison, and in the human records higher values are found in all nine cases. Looking at the values for the rats as a single group, as shown by the averages in the table, the test series gives the higher values for 2 of the 3 criteria, while for the humans all three values are higher in the test series. For 3 of the 5 mazes the rat values are larger in the test series, while all three mazes give higher values for the humans. Maze D gives the greatest evidence of negative retroaction with humans, but with the rats this same maze shows more evidence of positive retroaction. Maze F in the rat records gives the greatest evidence in favor of negative retroaction. As was found in absolute terms, so also we find in relative terms that the humans manifest a larger disturbing effect of a retroactive character.

7. An analysis of the types of error gives evidence of a greater disturbing effect in the test groups.

Pechstein[1] has shown in his maze experiments that subjects learn the maze in about the same number of trials when retracing is prevented as when this type of activity is allowed. Retracing thus plays but little part in the mastery of a maze so far as the number of trials is concerned. It thus follows that the retracing present in the learning of a maze is an incidental and useless

[1] Pechstein. Op. cit.

TABLE 25. AVERAGE PERCENTAGE OF LOSS.

Group	Test Trials	Test Errors	Test Time	Control Trials	Control Errors	Control Time
RATS						
B	20.8	6.3	10.2	13.2	3.7	8.2
C	4.0	2.8	2.4	1.1	3.0	1.1
D	11.5	4.0	2.0	12.7	9.3	5.8
E	57.9	17.5	12.2	85.0	12.4	7.0
F	50.2	49.9	44.6	36.2	13.5	11.4
Average	28.85	16.10	14.28	29.64	8.38	6.70
HUMANS						
B	25.0	12.2	13.2	6.0	0.8	2.0
C	34.0	45.0	26.6	19.0	3.8	7.8
D	132.0	27.5	35.5	42.6	7.2	18.0
Average	63.33	28.23	25.10	22.53	3.93	9.26

result of a peculiarity which manifests itself when an organism is in novel surroundings, or when it becomes lost or disturbed. The amount of retracing will in a measure represent the degree of disturbance due to novel conditions.

As a matter of fact, retracing was much more prevalent in the test experiments. Table 26 gives the data for the average number of retrace errors in the relearning of subjects manifesting a disturbance. The rats show a larger average number of retrace errors in the test group in all five cases of comparison, while in the human records the test group gives the higher averages in 2 of the 3 comparisons. Considering the rats and humans as single groups, we find that the test series has a greater number of retraces.

TABLE 26. AVERAGE OF RETRACE ERRORS IN THE RELEARNING OF SUBJECTS SHOWING A DISTURBING EFFECT.

Group	Rats Test	Rats Control	Humans Test	Humans Control
B	0.66	0.0	4.0	6.0
C	14.60	9.0	50.3	1.2
D	10.00	8.0	14.0	8.2
E	2.60	1.5		
F	26.30	4.1		
Average	10.83	4.52	22.76	5.13

Thus there appears to be a general tendency for more retracing to occur in the test series, which fact may argue for the presence of a disturbing or retroactive effect.

8. Certain peculiarities of behavior indicate a negative retroactive effect for Maze F.

By comparing the diagrams of Mazes A and F (Figs. 1 and 6), it is seen that the section numbered 6 to 10 as a cul de sac in Maze F, corresponds to an open section in Maze A, through which the rat must pass in his learning of this maze. After having mastered F, this additional route has to be added to his maze experience when transferred to Maze A; while in the relearning of Maze F this newly acquired habit must be again omitted. These conditions make it possible to determine in a fairly accurate manner whether or not the Maze A experience is functioning in the relearning of F. If the rats persist in entering the section 6-10, it is evident that the Maze A habit is functioning in such a manner as to interfere in again mastering F.

The record of the number of entrances into this section was kept for each subject. Rat A entered this section in 17 of his 22 trials; rat C, 13 out of 25 trials; rat E, 7 out of 7 trials; rat F, 8 out of 11 trials; rat G, 12 out of 20 trials; rat H, 4 out of 26 trials; while rats B and D made no entrances. The record for the control group is quite different. Five of the rats in this group entered this section only one time; one rat entered it twice, and one entered it three times. By this comparison, it appears that with the majority of the subjects in this group, the Maze A habit functioned in such a manner as to interfere in the relearning of Maze F.

9. The test series manifests the greater degree of imperfection of the maze habit on the first day's test.

Previously we have measured the degree of the imperfection of the habit by the time necessary to relearn the maze. This has been termed the relearning method. The usual method of measuring the imperfection of a habit in the experiments on retroaction is that of recall. In a maze experiment the nearest approach to the method of recall is to utilize the records of the activity of the first day in the relearning tests as a measure of the imperfection of the habit. We have made such a comparison, and the results are given in Table 27.

TABLE 27. FIRST DAY'S ACTIVITY IN RELEARNING.

	Test			Control	
	Errors	Time		Errors	Time
RATS					
B-A-B	1.9	46.8	B—B	0.75	37.0
C-A-C	9.4	113.2	C—C	5.3	61.7
D-A-D	2.8	61.4	D—D	2.8	62.8
E-A-E	2.2	22.3	E—E	1.0	19.5
F-A-F	23.4	154.6	F—F	8.8	47.8
Av.	7.9	79.7	Av.	3.7	45.7
HUMANS					
B-A-B	1.2	31.6	B—B	2.2	46.5
C-A-C	8.0	31.8	C—C	1.0	17.8
D-A-D	7.7	32.5	D—D	3.2	57.4
Av.	5.6	31.9	Av.	2.1	40.6

On examining the data in this table, we find that with the rats the test group has the larger number of errors and the greater amount of time for four of the five mazes, while the human results give the larger number of errors in two of the three comparisons and the greater amount of time in one of the three cases. Considering all of the rats and humans as two separate groups, we notice that the average for the rats is larger for the test group for both errors and time, while for the humans the test group has the larger record only for errors. With rats 31% of the subjects in the test groups were perfect in the initial trials, while in the control groups only 30% gave perfect records. In the human control groups 53% of the subjects manifested no disturbance in the trials of the first day, while only 24% of the subjects in the test groups gave evidence of no loss. Thus there appears to be a general tendency for the test series to manifest a greater degree of imperfection on the first day of the relearning activity.

B. RETROACTIVE EFFECT OF VARIOUS ACTIVITIES UPON THE SAME PROCESS.

Our second experiment deals with the retroactive effect which Mazes B, C, D, E, and F may exert upon the retention of Maze A. The same questions are at issue, as in the previous experiment, and records from test and control groups are necessary to

determine these issues. Several groups of subjects mastered Maze A; one of these groups then learned Maze B, another Maze C, a third Maze D, one Maze E, and a fifth group was transferred to Maze F. After an interval of thirty days each group relearned Maze A. Another group mastered A and waited an equal length of time and relearned the same maze; this is the control group. The groups learning another maze in the interval are the test groups. The difference between the results from the test groups and the control groups is termed the retroactive effect of the second maze upon the retention of Maze A.

The control group for rats was composed of 11 subjects, and in the human control group there were 6 subjects. The test groups to determine the retroactive effect of B upon A consisted of 9 rats and 5 humans; to show the effect of C upon A 9 rats and 6 humans were used; in the test groups for D there were 6 rats and 3 humans; 8 rats comprised the test group for Maze E. The records from 9 rats are employed to determine the effect of F upon A.

The relearning records for all individuals in both the test and control groups are found in Tables 28 and 29. The symbols A-B-*A*, A-C-*A*, etc., and A—*A* indicate the test groups and control group respectively. Chance, retroaction, or group peculiarities may have caused the difference between the records of the two groups. The selection of the groups prevented group peculiarities from functioning sufficiently to cause the differences. Again we are confronted with such wide individual differences that we are unable to make any accurate judgment between chance and retroaction. In this section we shall also confine ourselves to dealing with the factual comparisons.

1. Any disintegration due to time, or time plus retroaction, is an individual matter.

Many individuals were affected and some manifested no disturbance in the tests for retention. Exemptions from the influences are found in 8 of the 10 groups of subjects. Thirteen out of 52 rats, and 6 out of 19 humans gave evidence of no disturbing effect. Of the total number of subjects employed only 73.3% were affected by time or time plus retroaction. Thus we

TABLE 28. RETROACTIVE EFFECT OF VARIOUS MAZES UPON A.

RATS

	A-B-A							A-C-A					
	Trials		Errors		Time			Trials		Errors		Time	
Subj.	L.	R.	L.	R.	L.	R.	Subj.	L.	R.	L.	R.	L.	R.
1.	40	8	191	21	2009	146	1.	18	1	138	3	1254	62
2.	43	2	231	3	3260	31	2.	25	0	160	0	751	0
3.	20	2	224	7	4874	189	3.	59	1	318	52	3176	595
4.	30	16	194	33	1601	428	4.	45	0	295	0	899	0
5.	47	2	270	7	4907	41	5.	28	6	199	11	1087	129
6.	48	0	173	0	1388	0	6.	52	3	254	62	1786	605
7.	34	1	177	20	1452	58	7.	14	0	109	0	2187	0
8.	40	0	250	0	2210	0	8.	30	11	216	10	872	162
9.	49	0	166	0	1353	0	9.	42	5	246	11	1419	149
	A-D-A							A-E-A					
1.	76	2	299	2	2128	46	1.	35	4	150	3	2195	60
2.	31	12	184	27	1180	188	2.	47	3	162	5	2708	49
3.	27	7	144	10	922	84	3.	27	0	221	0	1084	0
4.	33	1	570	1	5112	25	4.	34	2	108	1	2166	53
5.	31	0	124	0	1384	0	5.	48	0	158	0	1213	0
6.	28	2	126	1	1582	76	6.	22	7	174	66	2465	596
							7.	26	2	136	9	573	51
							8.	44	5	169	4	1526	72
	A-F-A							A——A					
1.	36	4	170	6	710	60	1.	73	5	293	9	1773	101
2.	37	2	196	7	1016	64	2.	68	3	281	2	2279	54
3.	43	3	211	3	1307	49	3.	52	2	242	4	1684	46
4.	26	10	143	25	893	176	4.	27	20	131	35	797	306
5.	22	0	139	0	498	0	5.	70	9	265	7	4602	137
6.	33	4	169	12	802	65	6.	43	0	193	0	1077	0
7.	23	5	172	19	2196	117	7.	44	0	230	0	1227	0
8.	28	9	98	20	587	146	8.	72	9	356	11	2502	149
9.	23	4	144	13	616	59	9.	69	0	307	0	2088	0
							10.	16	8	143	24	1466	140
							11.	61	1	294	8	2409	38

TABLE 29. RETROACTIVE EFFECT OF VARIOUS MAZES UPON A.

HUMANS

	A-B-A							A-C-A					
	Trials		Errors		Time			Trials		Errors		Time	
Subj.	L.	R.	L.	R.	L.	R.	Subj.	L.	R.	L.	R.	L.	R.
1.	29	45	135	53	706	491	1.	32	14	212	26	1036	144
2.	7	0	95	0	384	0	2.	24	32	197	75	607	311
3.	15	0	83	0	329	0	3.	2	11	48	18	441	257
4.	22	0	181	0	1702	0	4.	39	19	318	18	943	167
5.	23	5	180	53	510	182	5.	34	26	157	57	631	285
							6.	47	5	152	19	1471	135
	A-D-A							A——A					
1.	18	11	691	14	1851	134	1.	18	0	211	0	1005	0
2.	5	6	442	15	1585	105	2.	7	4	68	8	363	61
3.	40	38	360	71	1385	415	3.	23	6	226	16	1118	110
							4.	49	0	531	0	1157	0
							5.	21	0	193	0	1437	0

again make the statement that if retroaction is present, it is confined in its operation to certain individuals.

2. In comparing the individual variability in relearning with that in the original mastery of the same maze, we find much wider variations in the relearning.

The records for the original mastery, in addition to the relearning records, are inserted in Tables 28 and 29. The column marked L gives the values for the original learning, and the one marked R presents the individual relearning records for the various subjects. The above generalization is obvious from an examination of the comparative data in this table. In order to facilitate the comparison, we have expressed the value of the average deviation in relation to the average in percentage terms. These percentages will be found in Table 30. The columns L and R give the values for learning and relearning respectively. For the rats the relative variability in the relearning is greater in all 18 cases of comparison, while in the human records there is a greater variability manifested in the relearning in 10 of the 12 comparisons. On the average the relearning values are approximately twice as large as the values for the original mastery.

The two exceptions noted above are to be found in the human records; however, on the whole there is no consistent difference between the rat and human records. The two exceptions with the humans may be due to the fewer number of subjects in these two groups. No consistent difference is apparent between the test and control groups, nor between the various mazes.

TABLE 30. INDIVIDUAL VARIABILITY IN LEARNING AND RELEARNING.

	Trials		Errors		Time	
Group	L	R	L	R	L	R
RATS						
A-B-A	18	110	15	97	46	101
A-C-A	37	97	29	108	42	92
A-D-A	34	91	53	114	51	67
A-E-A	23	65	14	125	37	110
A-F-A	21	50	16	52	37	52
A—A	29	87	22	85	36	81
HUMANS						
A-B-A	35	140	27	119	53	72
A-C-A	38	44	25	27	34	31
A-D-A	85	72	41	75	27	65
A—A	43	120	46	125	26	120

3. Our evidence fails to justify the conclusion that there is any correlation between the learning and the relearning records.

As in the former instance dealing with a similar correlation, we ranked the individuals according to their ability as manifested in the learning and relearning of the same maze. The correlation values between these two sets of data are given in Table 31. The majority of the values are too small to be significant, and only 16 of the 30 values are positive. From this it appears that there is no general tendency towards a positive correlation between the two sets of values. The differences between the humans and rats, the control and test groups, and the various mazes, are apparently not significant.

TABLE 31. CORRELATION BETWEEN LEARNING AND RELEARNING.

Group	Trials	Errors	Time
	RATS		
	Test Groups		
A-B-A	—.37	.28	.33
A-C-A	.08	.56	.42
A-D-A	—.31	.39	—.60
A-E-A	—.21	.32	.45
A-F-A	—.14	—.25	.25
	Control Group		
A—A	.13	—.04	.21
	HUMANS		
	Test Groups		
A-B-A	.90	.38	.40
A-C-A	.00	.13	—.82
A-D-A	1.00	—1.00	—.50
	Control Group		
A—A	.00	.00	—.30

The result in this instance strengthens the validity of our conclusion in the corresponding section of the first experiment: The ability manifested by individuals in learning a maze is no index to their relative ability in relearning the same maze. Again we conclude that individual susceptibility to the disintegrating effects of time is responsible for the pronounced variability in the relearning records.

4. In the test series a greater percentage of the subjects gives evidence of some degree of disintegration of the old habit, than is found in the control series. Retroaction may be operating to cause this greater effect.

The data in support of the above statement will be found in Table 32. There was 76.08% of the total number of rats used in the test series disturbed by the influences, while 72.7% were affected in the control series. The human records show 80% and 40% affected in the test and the control series respectively. More of the rats were affected in 3 of the 5 test groups, while in 2 of the 3 test groups of the humans there was a larger percent affected. Two of the human test group had 100% of the subjects affected. A greater susceptibility to the influences is apparent in the test series.

TABLE 32. PERCENTAGE OF SUBJECTS AFFECTED.

	Rats		Humans	
Group	Test	Control	Test	Control
A-B-A	66.6	72.7	40	40
A-C-A	66.6		100	
A-D-A	83.3		100	
A-E-A	75.0			
A-F-A	88.9			
Average	76.08	72.7	80	40

5. For those subjects affected the average amount of disintegration is on the whole slightly higher in the test series.

For evidence in support of the above statement see Table 33. Higher values are found in the test series for the rats in 7 of the 15 cases of comparison. In the human records the test series give higher values in all 9 instances of comparison. Looking at the rat and human values as single groups, higher values are present with rats in two of the three criteria, with humans in all three criteria. No single maze in the rat records gives uniformly higher values in the test series, while all three mazes do so for the humans. For the rats Maze D gives the greatest evidence of positive retroaction, while Maze C manifests the greatest amount of disturbance. In the human records Maze B gives the greatest evidence for negative retroaction. The results indicate that the humans are more susceptible to negative retroaction than are the rats.

6. The disintegration or loss during the thirty day interval is on the whole somewhat higher in the test series when the results are stated in percentage terms.

TABLE 33. AVERAGE RELEARNING RECORDS FOR SUBJECTS MANIFESTING DISINTEGRATION.

Group	Test Trials	Test Errors	Test Time	Control Trials	Control Errors	Control Time
RATS						
A-B-A	5.17	15.17	151.00	7.09	12.50	121.38
A-C-A	4.50	22.83	263.67			
A-D-A	4.80	8.13	87.20			
A-E-A	3.83	14.67	146.83			
A-F-A	5.11	14.38	92.00			
Average	4.68	15.03	148.14	7.09	12.50	121.38
HUMANS						
A-B-A	25.00	53.00	336.50	5.00	12.00	85.50
A-C-A	17.83	35.50	216.50			
A-D-A	18.33	33.33	184.66			
Average	20.39	37.27	245.89	5.00	12.00	85.50

The comparative data upon which the above generalization is based are given in Table 34. The human test series give higher values in all nine cases of comparison, while the test series in the rat records give higher values in 7 of the 15 comparisons. Considering the average for the humans as a single group, higher values are found in the test series by all three criteria; the test series with the rats give higher values for 2 of the 3 criteria. Only Maze F gives uniformly higher values in the test series for the rats, and hence manifests a negative retroactive effect; Maze B evidences the greatest positive retroactive effect. All three mazes give uniformly higher results for the humans in the test series. The humans manifest a greater negative retroactive effect than do the rats.

TABLE 34. AVERAGE PERCENTAGE OF LOSS.

Group	Test Trials	Test Errors	Test Time	Control Trials	Control Errors	Control Time
RATS						
A-B-A	10.5	5.1	4.9	15.2	5.4	6.1
A-C-A	9.3	6.3	10.9			
A-D-A	13.3	4.2	5.8			
A-E-A	9.4	6.5	7.0			
A-F-A	16.0	8.3	9.8			
Average	11.7	6.08	7.68	15.2	5.4	6.1
HUMANS						
A-B-A	39.0	13.8	21.2	14.6	3.8	5.4
A-C-A	139.0	23.8	32.5			
A-D-A	92.0	8.3	14.7			
Average	90.0	15.3	22.8	14.6	3.8	5.4

7. A greater disturbing effect in the test series is evident from an analysis of the types of error.

In this connection we shall consider only the subjects that manifested some degree of disintegration. The comparative data for this topic are given in Table 35. The rats have a larger average number of retrace errors in the test series for 4 of the 5 mazes, and the human test series give the greater number of retraces in all three mazes. Considering the humans and rats as single groups, the test series for each group has the larger average number of retraces. Granting the hypothesis that the presence of retrace errors is an evidence of disturbance, we have here some evidence in favor of a retroactive effect.

TABLE 35. AVERAGE OF RETRACE ERRORS IN THE RELEARNING OF SUBJECTS MANIFESTING DISINTEGRATION.

	Rats		Humans	
Group	Test	Control	Test	Control
A-B-A	10.16	4.12	34.50	8.00
A-C-A	18.66		18.00	
A-D-A	0.00		8.66	
A-E-A	12.66			
A-F-A	4.87			
Average	9.27	4.12	20.38	8.00

8. A greater degree of imperfection of the maze habit is found with the test series on the first day of the test for retention.

In considering the retroactive effect in the preceding topics of this section, we have utilized the relearning or saving method. In this topic we wish to approximate the method of recall; hence we shall make use of the records of the activity of the first day in the relearning tests. The results for both the test and control groups will be found in Table 36.

By comparing the data in this table, we discover that for the rats the test group has the larger number of errors in four of the five cases of comparison, and the larger amount of time in three of the five cases. The test groups for the humans give larger values in the error column in all three comparisons, and for time they have the larger average in two of the three cases. The averages for all the members of the several test groups are larger than for those of the control group for the humans and

TABLE 36. FIRST DAY'S ACTIVITY IN RELEARNING.

	Test			Control	
	Errors	Time		Errors	Time
RATS					
A-B-A	5.2	64.1	A—A	4.0	47.4
A-C-A	12.8	162.9			
A-D-A	2.5	43.2			
A-E-A	7.6	82.6			
A-F-A	4.4	37.2			
Av.	6.5	78.0			
HUMANS					
A-B-A	10.6	44.2	A—A	0.4	26.2
A-C-A	6.8	47.6			
A-D-A	4.8	24.8			
Av.	7.4	38.8			

the rats by both criteria. We believe that this evidence is sufficient to warrant the statement that there is a general tendency for the test groups to manifest a greater degree of imperfection on the first day of the relearning activity.

C. SUMMARY.

In treating the experimental results of our study of retroaction, we refrained from making any general conclusions. We have dealt thus far mainly with the factual material. We shall now summarize the results under two headings, and make our general conclusions.

I. Retention.

1. The groups exhibit a wider range of individual variability in relearning a maze than in its original mastery. But two exceptions to this generalization were found in 78 cases of comparison. This greater variability is not a function of the maze, the kind of subject, nor is it dependent upon the type of activity interpolated between the learning and relearning. It is primarily a function of the individual's susceptibility to the disintegrating effect of time.

2. There is no correlation between the learning and relearning records. The majority of the correlation values are too small to be significant; neither are they consistently positive or negative. Of 78 cases, 44 were positive, 30 negative and 4 cases

showed zero values. Subjects manifesting good ability in mastering a maze may thus do poorly in relearning the same maze. The individual differences either in mastering or relearning a maze are thus due to chance rather than representing individual differences in ability. Neither is there any correlation between learning records and retentive capacity. Both quick and slow learning groups may exhibit the maximum of retentive capacity, and both classes may be equally susceptible to the disintegrating effects of time. This relation between acquisition and retentive capacity is not dependent upon the type of subject, nor upon the character of the intervening activity.

3. Human subjects manifested a slightly greater retentive capacity of sensori-motor habits than did the rats. This conclusion is based upon a comparison of the relearning records of rat and human subjects for the same mazes, viz. A, B, C, and D. Only those subjects employed to test the disintegrating effect of time were used in this comparison.

A greater percent of rat subjects showed some disintegration in three of the four maze comparisons. For Maze C a larger percentage of the human subjects evidenced some degree of disintegration. Of the subjects that forgot part of the habit during the interval, the average relearning records for all three criteria of measurement are larger for the rats for Mazes A and B; the same condition prevails for Maze D for errors and time, and for Maze C for time alone. Thus the rats have the larger averages in 9 of the 12 comparisons. Considering the rats and humans as single groups, the averages for the rats are larger by all three criteria. The average percentage of loss is on the whole larger for the animals. The rats have the larger values by the three criteria for A and B, and by errors for Maze D. The humans manifested a higher percentage of loss by all three criteria on Maze C, and on Maze D by trials and time. The average of the percentage values for the rats and humans as single groups is the larger for the animals by errors only, the humans having larger values for trials and time. This result is perhaps due to the fact that the human group on Maze D exhibited a very high percentage of loss by trials and time, due

to an individual peculiarity. In the first day's activity in the tests for retention, the rats evidenced the greater amount of disturbance. The averages for the rats are the larger in 5 of the 8 comparisons. As single groups the rats have the larger values for both errors and time.

4. The degree of retention is a function of the maze activity. In comparing the different mazes in respect to retention, we find that for human subjects Maze D gives the largest average percentage of loss, and Maze B the smallest percentage of loss by all three criteria. A similar condition is noticed to exist with rat subjects. To test whether this is a real difference or a mere matter of chance, we figured the correlation between the percentage of loss due to time and the difficulty of mastery. The mazes were arranged in order of their greatest difficulty, and again arranged in their order of greatest percentage of loss after a thirty day interval. The values for the rats are —.542, —.922, and —.714; and for the humans —.400, —.725, and —.800. Thus all of the six values are seen to be negative. This means that the maze which required the greatest effort to master was retained better, and that maze requiring the least effort to master manifested the greatest percentage of loss; in other words, this means that the deeper a motor habit is driven in by prolonged effort, the longer and better it will be retained.

5. A positive correlation exists between any two of the three criteria used in measuring retentive capacity.

The subjects in each group were ranked from the lowest to the highest by each of the criteria, and the correlation was computed between trials and errors, trials and time, and errors and time. This procedure gives us 30 correlation values, all of which are positive. Of the thirty values, 9 were perfect and 15 were above .90; four were between .70 and .80, one .52, and one .38. The degree of correlation is not a function of the maze, nor of the type of subject employed. The relation between any one pair of criteria is no more significant than that existing between any other pair. These results indicate that we can utilize one, any two, or all three criteria in the measurement of retentive capacity and obtain practically the same results.

II. Retroaction.

1. The greater degree of disintegration occurred for the test groups. This result indicates that negative retroaction was present in our experiments. The difference is not great, but it is consistent for all rubrics of comparison for both rats and humans, and in both experiments. The validity of the conclusion must be based primarily upon the consistency of the results. The acquisition of any maze activity must thus be regarded as exerting some disintegrating effect upon maze habits previously mastered. The evidence in support of the above conclusion follows.

(a) On the average a greater percent of subjects was affected in the test series. This result obtained for both humans and rats in both experiments. The test series manifested the larger percentage in 3 of the 5 mazes for rats in both experiments, and in 2 of the 3 mazes for humans in each of the experiments.

(b) Limiting the comparison to those subjects affected, the rats exhibited the greater disintegration in the test series stated in absolute terms, in 5 of the 6 comparisons. The humans also exhibited the greater disintegration by all three criteria of measurement for both experiments. Considering the mazes as units, the humans gave the poorer records in the test series in each of the 18 instances of comparison. Likewise, the rats made poorer records in the test series in 20 of the 30 comparisons.

(c) The test series gave the poorer records in both experiments when the results are stated in relative, or percentage terms; that is, the test series exhibited the greater percentages of loss. The rats as a group gave the poorer average records for both errors and time in each of the experiments. The records for the humans were the poorer by all three criteria for both experiments. Considering the mazes as units, the humans gave the poorer records in each of the 18 instances of comparison, and the rats for 19 of the 30 cases.

(d) The average amount of retracing was the greater in the test series for both humans and rats in both experiments. The retracing for the rats was the greater for 9 of the 10 mazes, and for 5 of the 6 mazes with the human subjects.

(e) The greater disintegration occurred in the test series when measured by the records of the initial trials. This result obtained for the rats as a whole in 4 of the 5 instances of comparison, and for the humans in 2 of the 3 comparisons, in both experiments; it was likewise true for the rats in 9 of the 10 mazes, and for the humans in 4 of the 6 mazes.

2. The existence of retroaction is a function of the individual. In practically every group in both experiments, some subjects were affected and some were not. Of the total number of subjects employed in the first experiment, 37% manifested no disintegration, and in the second experiment 26.7% of the subjects gave no evidence of a disturbing effect.

3. Human subjects are more susceptible than rats to the disintegrating effect of retroactive influences.

For purposes of this comparison, we shall utilize only the records for Mazes A, B, C, and D upon which both rat and human subjects were employed. This gives us six cases of comparison, three in each experiment. To determine the amount of retroaction present in each test, we subtracted the records of the control group from those of the test group; the difference may be said to be due to retroaction. Upon a basis of a comparison of these results, we have the following evidence in support of the above conclusion.

A larger percentage of the human subjects manifested some degree of negative retroaction. The percentages are considerably larger for the humans in 4 of the 6 cases. The two exceptions are found in noting the effect of B upon A and of A upon B; the relative susceptibility of the two groups may thus be a function of the maze. In three of the human groups 100% of the subjects were affected, while in no instance did any of the rat groups have all of the subjects affected.

Stated in absolute terms, the average amount of disturbance for the human subjects is the larger in all six of the mazes. In the 18 instances of comparison, the values are the larger in the human records in 17 cases. Taking the groups as units in the first and second experiments, the humans have the larger averages in all six comparisons.

Making the comparison in terms of percentage of loss, we find that the humans manifested a greater degree of disintegration in all six mazes, and by all 18 instances of measurement.

The human subjects manifested the greater disturbance as measured by the amount of retracing. The average for the humans is larger in four of the six mazes. Considering the subjects in each experiment as units, the averages are much larger in both cases for the human subjects.

In the first day's activity of the relearning tests, the humans evidenced a greater disturbance in 4 of the 6 mazes when measured by errors, and in 2 of the 6 mazes when measured by time. The result by time may readily be attributed to the fact that the rats in returning to a maze problem after an interval of several days are quite cautious at first and travel rather slowly.

4. A positive correlation was found to exist between any two of the criteria employed in measuring the retroactive effect. The ranking method was used, and the values were determined for trials and errors, trials and time, and errors and time. In this manner we secured 12 values evenly divided between the rats and humans. Nine of the 12 values are positive. The validity of the conclusion depends upon the consistency of the positive values. This result is not a function of the maze, nor the type of subject. A much closer and more significant relation exists between errors and time than between any other pair. Of the four values measuring this relation, three are perfect and one .70, while none of the other values are above .50. In measuring the retroactive effect of one maze activity upon another, we can thus utilize one, two, or three of the criteria without materially changing the results.

5. Direction is not a deciding factor in determining the amount of retroaction present. The manner in which our experiment was arranged makes it possible to determine whether the retroactive effect of two activities upon each other was the same or different; thus we have the retroactive effect of A upon B, and of B upon A, and so with the other pairs of mazes. No new data are needed; a comparison of the data employed in determining the amount of retroaction present supports the above

conclusion. When the mazes are ranked according to the amount of retroaction present, we find that in both directions with rat subjects A and F stand first, and A and D last. Each of the other three pair has a slightly different rank according to direction. In the human records we have a similar result. The largest disturbing effect occurred between A and C in both directions, while the rank in the other two pairs of mazes differs slightly for the two directions. As a matter of chance, we would expect some difference due to the change of direction. We believe that the fact that three pairs of mazes are not affected by the change of direction is more significant than the difference in the other pairs, and that the above conclusion is justified.

6. The degree of retroaction is a function of the interpolated maze activity. The easier is the maze to learn, the greater is the resulting negative retroaction. The various mazes were ranked in their order of difficulty of mastery. These were also ranked in order as to their retroactive effect. Correlation values between the two values were computed. Five of the six values are negative, three of which are perfect and two above .60.

A positive retroactive effect was secured for Mazes A and D with rat subjects. The interpolation of A was beneficial upon the remastery of D by all three criteria. Likewise D exerted a favorable effect upon the relearning of A by all three criteria. This fact indicates that retroaction may be positive in character with some pairs of mazes. Additional evidence in support of the above conclusion is had as a result of computing the correlation between transfer and retroaction. These values will be discussed in the following topic.

7. There is a negative correlation between positive transfer and negative retroaction. Those conditions which produce the maximum amount of positive transfer give the least amount of negative retroaction. We ranked the mazes according to the percent of transfer present in both of the experiments dealing with that topic. We also ranked the mazes according to the amount of negative retroaction present determined by subtracting the records of the control groups from those of the test groups. From these ranks we computed the correlation between mazes;

in the first instance the correlation is between A-*B* etc. in the transfer and A-*B* etc. in the tests for retroaction, while in the other case the values are between the records of A-*B* etc. in the transfer and B-*A* etc. in the retroaction. This was done for both experiments, thus giving us 24 values in all. Twenty-one of the values are negative, 5 of which are perfect, 7 are —.70 or above, and the remaining values are around —.50. These results mean that the greater the assistance rendered by the first maze experience in the mastery of the second maze, the less disturbance will there be in relearning the first maze.

The same relation between retroaction and transfer is apparent from a comparison of the rat and human subjects. The rats manifested a greater ability than did the humans in the transfer experiments, while they exhibited the lesser susceptibility to retroactive disturbances.

D. Theoretical Discussion.

Two explanatory conceptions of retroaction which possess some degree of logical plausibility may be suggested.

1. The Transfer Hypothesis. This conception has been suggested by DeCamp. The retroactive effect is regarded as a case of transfer. In the maze sequence A-B-A, the term retroaction refers to the effect of the acquisition of the B habit upon the subsequent functioning, or relearning of the A habit. The transfer hypothesis assumes that this effect is mediated by the simple transference of certain elements of the B habit to the succeeding maze A situation. Theoretically this transference may operate either in an advantageous or detrimental manner; in other words retroaction may be positive or negative.

2. The Disruption Hypothesis. In the maze sequence of A-B-A, we know that transfer obtained in proceeding from A to B. Certain elements of the complex A habit have been transferred to and utilized in the maze B situation. The hypothesis assumes that this incorporation of certain components of the A habit into the subsequently acquired B habit must necessarily involve its partial disruption and disorganization. The A habit is a complex system whose component elements have been

welded and associated into a unitary whole. The utilization of certain of its parts in a new situation must involve their dissociation from their former contextual relations, and the habit must thus be partially disrupted and disorganized. The remastery of A after the acquisition of B must repair not only the ravages due to time, but dissociate these elements from their new context and weld them anew into their original system of relations. According to the disruption hypothesis, the retroactive effect will invariably be negative in character.

The two hypotheses are not antagonistic or mutually exclusive. They may supplement each other. The effect of the B habit upon the functioning, or remastery of A may be due in part to the process of disruption, and in part to the transference of certain components of the B habit which are carried over to the subsequent A situation.

Several of our factual data are relevant to a consideration of the validity of the disruption hypothesis.

1. Transfer was present for all pairs of mazes employed in our experiments, and some degree of retroaction was manifested for each of these maze situations. This fact supports the hypothesis, for it assumes that retroaction is a necessary by-product of the previous transfer process.

2. All subjects, both human and animal, manifested the phenomenon of transfer, yet a certain percentage of these individuals (33) were not subject to any retroactive effect. This fact constitutes a serious objection to the acceptance of the hypothesis. These individual exceptions can be explained by the supposition that the retroactive effect is the combined result of both disruption and positive transfer, and that these two antagonistic tendencies were equal in these particular cases.

3. According to the hypothesis, retroaction will invariably be negative in character. Our results support this assumption in fourteen of the sixteen pairs of mazes. The pair A-D constitutes a possible exception with the animal subjects. We have previously indicated that there are good reasons for concluding that the retroactive effect was positive for this pair of mazes.

4. Transfer and retroaction are inversely correlated; those

conditions which give the greatest amount of positive transfer give the least subsequent negative retroactive effect. This fact presents some difficulty to the hypothesis, for it is logical to suppose that the degree of disruption will vary directly with the degree of transfer. This apparent exception to the validity of the theory may be obviated by the following mode of explanation. Both positive and negative transfer will produce a disruption of the first habit, and thus mediate a negative retroactive effect. We may assume that the disrupting effect of negative transfer will be greater than in the case of positive transfer. Our experiments on the transfer phenomenon have demonstrated that the total transfer effect is the sum of both positive and negative elements, although the positive factor predominated in every case. This conception explains the varying degree of transfer for the different conditions under which the experiments were conducted. The total effect is minimal when the negative factors approximate the positive in strength. The greatest total effect is achieved when the relative functional efficiency of the positive factors is at a maximum. Granted that the negative factors possess the greater disrupting efficacy, it is thus possible for the degree of disruption, and hence for the degree of retroaction, to be inversely related to the degree of transfer.

5. The retroactive effect was manifested on the first day's trials. This initial inefficiency of the A habit in the test group as compared with the control group indicates the presence of some previous disrupting or disorganizing process. The fact can, however, be easily explained in terms of the transfer hypothesis.

The following facts are pertinent to a consideration of the validity of the transfer hypothesis concerning the nature of the retroactive effect.

1. The retroactive effect was negative in fourteen of the sixteen pairs of mazes. If this effect is mediated by a transfer process, we are forced to conclude that this transfer was negative in the majority of cases. The same pairs of mazes were utilized in the transfer experiments and the effect was positive in every case. In other words, the hypothesis assumes that

transfer is negative when previous experiments on the same mazes have demonstrated that the effect is positive.

A certain percentage of subjects manifested no retroactive disturbance, and yet all subjects exhibited transfer for the same pairs of mazes. The hypothesis is thus forced to reconcile the occasional absence of transfer in the one experiment with its invariable presence in the other, the same pairs of mazes being used in both cases.

The above facts, however, do not disprove the transfer conception of the retroactive effect, for the two experiments differed in several important respects, although the same pairs of mazes were employed in both. a) In the transfer experiments we were concerned with the effect of the first habit upon the acquisition of a second activity. The retroactive experiment was concerned with the effect of a second habit upon a third activity. In a series of successive activities, it is possible that positive transfer may obtain for the first pair while a negative effect will be exhibited by all succeeding pairs of the sequence. Some recent experiments in this laboratory, however, have disproved this assumption; some degree of positive transfer was invariably obtained in a sequence of five maze activities. b) The transfer experiment was concerned with the effect of a maze habit upon the *original mastery* of a second maze; retroaction refers to the effect of a maze habit upon the *remastery* of a second maze. In the one case, we are concerned with the utilization of a habit in the development of a *new* habit, and in the other with its utilization in the perfection of an *old* habit. The character of the transfer process may differ radically in the two cases. There are two considerations which support this assumption. (1) In the transfer experiments the subjects first develop the maze A habit. They are now transferred to a similar situation, viz., Maze B. This new sensory situation, because of its similarity, arouses or stimulates certain components of the previous A habit. The conditions of the retroactive experiment are radically different. The subjects have acquired two habits, A and B, in succession. They are now transferred back to the old Maze A. This sensory situation now tends to rearouse both the A and B habits.

Conflict and interference between the two systems must be the logical result. The conflict may apply to the process of recall, the transfer of the B habit operating to repress or to prevent the rearousal of the A habit which is to be remastered. Certain components of both systems may be reinstated and the conflict will result from their functional antagonism. In either case, confusion and an increased difficulty of mastery will result. In other words, transfer will be detrimental in the remastery of a maze although beneficial in its original mastery. (2) The transfer experiment demonstrated that the transfer effect was limited almost exclusively to the early stages in the development of a habit. The process of transference starts the subjects at an advanced stage of the problem and exerts relatively little effect upon the final development of the habit. In other words, transference exerts radically different effects upon the initial and the final stages in the development of a habit. In the retroactive experiment we are dealing with the remastery of a partly disintegrated habit. The habit is largely retained, the subjects are introduced to the problem at an advanced stage of mastery, and the process of relearning is essentially similar to the final stages of the development of a new habit. This fact is evident from a comparison of the curves of learning with those of relearning in the tests for retention. The relearning curves do not exhibit the pronounced initial descent characteristic of the typical learning curve; they approximate in character the latter part of the normal curve. Since transference exerts radically different effects upon the initial and the final stages of learning, one can not assume that transfer must produce the same effects in our two experiments; in fact one must assume that the effects are essentially different.

2. The transfer experiment does prove, however, that transference of some sort is always in evidence throughout a sequence of maze activities, and necessitates the conclusion that transfer of some kind did occur in the retroactive experiments, although it will not justify any assumptions as to the nature and degree of these effects.

3. The existence of a transfer process in the retroactive experiment is proven beyond doubt by certain facts which have been described on page 68. As previously noted, Mazes A and F were so designed in relation to each other that any transference from one to the other is easily detected. Both possess a common section 6-10. This section constitutes a part of the true pathway in A, but it is one of the cul de sacs in F. In the retroactive sequence of F-A-F, the subjects are first required to avoid this section, then to develop the habit of entering it in A, and then to avoid it again in the mastery of F. If the habit of entering this section acquired during the mastery of A is transferred to the subsequent F situation, it will be manifested by a greater number of entrances into this section than are made by the control group that has been given the maze sequence F—F. Such results were, in fact, secured. The average number of entrances into this section by the test and control groups respectively was 11.25 and 1.71. The corresponding number of trials in which this section was entered was 7.62 and 1.42. The number of trials necessary to eliminate this tendency was 10.35 and .085 for the test and control groups respectively. The total error scores made in this section for the two groups were 35.37 and 5.28. All of the above values are also much larger for the test group when stated in percentage terms.

These facts prove not only that a transference process does exist in the retroactive experiment but also that it was negative in character for the maze sequence F-A-F. It is also well to note that the greatest negative retroactive effect was secured for this particular pair of mazes.

4. The negative retroactive effect was evident in the first day's trials. This fact can be explained by the hypothesis. Our experiment demonstrated that the process of transference was more effective upon the initial trials than upon the later stages. If the negative effect is due to the confusion or conflict between the two systems of habits, this confusion will necessarily be present at first.

To summarize: The existence of a negative transference process has been demonstrated for one pair of mazes in the

retroactive experiment; the situations in our two experiments are so different that one is justified in assuming (unless proof to the contrary is advanced) that both sets of results were mediated by transfer; all of our factual data concerning the phenomenon of retroaction are readily explicable in terms of the transfer conception. On the other hand, there is no positive proof of the existence of a disrupting process. The conception explains some facts quite readily, some with difficulty, while others are incapable of explanation in such terms. We are thus forced to conclude that the retroactive effect is to be explained mainly, if not wholly, in terms of transfer, although it may be due in part to a process of disruption. It is well to remark that retroaction in so far as it can be reduced to transfer can not be regarded as a phenomenon *sui generis*.